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A STUDY OF THE PHOTOSYNTHESIS OF SUGAR CANE[1]

By GERMAN G. YAP

This work deals principally with the amount of carbon dioxide which the leaf absorbs from the air during the process termed photosynthesis. It has been known for a long time that carbon dioxide gas, which the leaf absorbs from the air, reacts with the water in the green tissues of leaves in the presence of light to form carbohydrate foods. The process may be illustrated by the following equation: $6CO_2 + 6H_2O = C_6H_{12}O_6 + 6O_2$. The first product of photosynthesis is presumably a soluble sugar, which is changed into other forms of carbohydrate food. During rapid photosynthesis starch accumulates in the leaf of sugar cane. Carbohydrate food is dissolved and moves slowly from the leaf to the stem, where it accumulates in the form of cane sugar. The importance of this process cannot be too strongly emphasized. According to Peirce (1), "The most important chemical reaction in all nature, from the standpoint of man and other living things at least, is that which results in the combination of carbon dioxide and water into sugar."

There has been very little work done which deals with the photosynthesis of important crop plants. Such experiments as have been made on the photosynthetic activity of leaves under natural conditions have been performed by means of the method involving measuring the increase in the dry weight of the leaves. This method is indirect and involves many sources of error. A study of the assimilation of sugar cane was made in Java by Kuiper (2), who used the

[1] Thesis presented for graduation from the College of Agriculture, No. 114; Experiment Station contribution, No. 36.

dry-weight method. He showed conclusively that the dry-weight method is not sufficiently precise to show variations in the rate of photosynthesis of sugar cane. His results probably do, however, give an approximation of the normal rate of photosynthesis of sugar cane during the dry season in Java.

The method employed in the present work for studying the process of photosynthesis is the well-known method involving the measurement of the amount of carbon dioxide gas absorbed by the leaf. This method involves fewer assumptions than the dry-weight method and is considered to be more accurate than the latter. The apparatus and procedure in this study was essentially the same as that reported by Dr. McLean (3) in his work on carbon dioxide absorption by coconut leaves. Some modifications of his procedure were made.

The object of the present work was to determine the rates of photosynthesis of sugar cane leaves at different stages of maturity. The work was performed at the College of Agriculture and included measurements for eleven days during the month of March, 1919.

MATERIALS AND METHODS

A portion of the sugar cane leaf was inserted in a glass cylinder having an inside diameter of about 3.5 centimeters and a length of 62.0 centimeters. The leaf was held in the cylinder by means of a split cork, grooved at the center. Canals had been made at several places in the cork to facilitate the passage of air from the outside to the inside of the cylinder. In the bottom half of the cork a thermometer was inserted to determine the temperature of the air inside the chamber. The thermometer was shaded by the leaf. A glass tubing with a piece of cork was loosely inserted in the upper half of the cork. This served to remove the moisture which collected in the cylinder when transpiration was rapid. A rubber tubing connected the glass cylinder to a pair of bottles containing sulphuric acid, through which the air bubbled before it entered a tube containing baryta water. The reason for passing the air through sulphuric acid was to remove the moisture which would otherwise have diluted the solution in the baryta tube.

The baryta tube (Pettenkofer) contained 300 cubic centimeters of barium hydroxide solution, $Ba(OH)_2$, of known alkalinity. The air passed through the baryta water in a regular series of bubbles, and all of the carbon dioxide which was present was removed. The air, free from carbon dioxide, then bubbled through a baryta bottle which served as a wash, and contained 160 cubic centimeters of barium hydroxide of the same concentration as that in the baryta tube. The use of the wash bottle was to find out whether or not all of the carbon dioxide was caught in the baryta water. The air again bubbled through a sulphuric acid solution before it entered a large tank which was used as an aspirator.

This tank was cylindrical, 82 centimeters high and 67 centimeters in diameter, and was set on braces which held it about a meter from the ground. The upper cover of the tank was provided with two holes placed opposite one another. One hole was 2.5 centimeters in diameter and the other, 5 centimeters in diameter. Into the small hole, two glass tubes were inserted and held by means of a rubber stopper. The two tubes were bent down so that one connected the tank with the sulphuric acid bottle, and the other connected the tank with a bottle of water placed below the tank. The use of the tube which was immersed in the water

in the bottle was to indicate the pressure of the air inside the tank. There were three tubes inserted in the larger hole. One tube bent down and served as a siphon. The other two were so connected and bent as to indicate the level of the water in the tank.

An outflow tube was suspended in the air by means of a string which ran through a 1.1 pulley and was tied to the key that set the hour hand of a clock. At the end of the outflow tube, there was a rubber tubing provided with a pinch cock to stop the flow of water, if necessary.

The clock and the pulley arrangement regulated the head of water. This arrangement, therefore, regulated the rate of flow of water from the aspirator tank. The head, by this arrangement, lowered about five centimeters an hour.

A single plant was used in all the tests here reported. This belonged to a ratoon crop of Louisiana striped sugar cane. It was about three months old and was growing in one of the trial beds of the College. There were four hills of this cane, and the particular plant used was apparently normal and healthy. The plant was watered every other day during the course of the experiment. Two new leaves appeared during the period of the experiment.

A *check* apparatus, which was exactly the same as that used for the experiments except that it contained no leaf, cork swab, and thermometer, was placed by the side of the apparatus inclosing the leaf. The outflow tube of the check apparatus was tied to that of the apparatus and connected with the clock and pulley arrangement.

The solution used was drawn directly into the wash bottles and baryta tubes each evening preceding the morning test. Three hundred cubic centimeters of the barium hydroxide solution of known alkalinity were drawn into the baryta tube. The tube was tightly plugged with a rubber stopper at one end with a stop cock and rubber tubing at the other. One hundred and sixty cubic centimeters of the solution were introduced into the wash bottle, which was then tightly closed with a paraffined cork. Two baryta tubes and two wash bottles were needed for each test. The tubes and bottles were taken to the apparatus and set in their proper places. It was necessary to take particular care that all stop cocks and connections were tight. The tank was filled with water to its full capacity, and no air space was left in the tank at the beginning of the test. When the tank was full, the large hole was tightly plugged with a rubber stopper. The apparatus, set up in this manner, was left during the night.

Before the test was begun on the following morning, the water level in the manometer was determined, and this line was designated as zero. The outflow tubes were then set at such an angle as to make the head about 50 centimeters. The leaf was then placed in the glass cylinder, or leaf chamber, and the temperature was taken. The flow of water from the aspirator was started by opening the stop cock of the siphon and all other cocks and valves in the apparatus. The flow began in less than a minute after opening all the cocks.

At about seven or eight minutes before twelve o'clock the water level in the pressure tube and the temperature were recorded. The cocks were then closed and the flow of water stopped. The water level in the tanks was then determined and recorded. The baryta tubes and wash bottles were replaced by new ones prepared at about eleven-thirty in the morning. The apparatus was then started again, the interval required for changing the apparatus being about fourteen

minutes from the time of stopping the first test. The baryta and the wash bottles were taken to the laboratory. The solution in each baryta tube was emptied into a clean, dry bottle, which was then corked tightly. The solutions were allowed to stand for a period of one or two hours before titrating them.

For titration three 25 cubic centimeter samples were drawn directly from the wash bottle through a burette. A solution of hydrochloric acid of known concentration were used. The indicator used was methyl orange. In cases where the titration of two samples agreed, a third sample was not tested. The solution from the baryta tube was titrated in the same manner, except that one 25 cubic centimeter sample was first used, and then one or two 50 cubic centimeter samples. In case the first 50 cubic centimeter sample agreed with the 25 cubic centimeter sample, the reading was taken as final. The samples were drawn into Erlenmeyer flasks which were not washed after completing a titration, but were simply allowed to drain.

RESULTS

TABLE I.—*Results as obtained from titrations of the samples used in the experiments, and the data necessary for the computation of results.*

Leaf No.	Date March 1919.	Time.	Normality, HCl.	Normality, $Ba(OH)_2$	Control.			Test.				Area of leaf used.
					Titration.		Vol. air.	Titration.		Vol. air.	Temp. air.	
					W. B.	P. T.		W. B.	P. T.			
											°C.	*sq. cm.*
3	10–11	6 p. m.	0.0542	0.0605							25.0	
		6 a. m.	0.0542	0.0605	27.90	50.15	73.32	27.90	48.30	63.32	22.0	44.75
2	11	6 a. m.	0.0542	0.0605							22.0	
		12 noon	0.0542	0.0605	27.90	52.35	41.04	27.90	53.90	48.42	45.0	44.46
2	11	12 noon	0.0542	0.0605							45.0	
		6 p. m.	0.0542	0.0605	27.90	50.90	71.34	27.90	52.20	65.78	26.0	44.46
2	11	6 p. m.	0.0542	0.0605							26.0	
	12	6 a. m.	0.0542	0.0605	27.90	50.20	78.91	27.90	49.15	77.66	21.0	44.46
4	12	6 a. m.	0.0542	0.0605							21.0	
		12 noon.	0.0542	0.0605	27.90	51.30	51.11	27.90	53.50	73.59	43.5	67.04
4	12	12 noon.	0.0542	0.0605							43.5	
		6 p. m.	0.0542	0.0605	27.90	53.00	39.57	27.90	54.80	35.52	26.5	67.04
1	13	6 a. m.	0.0542	0.0564							21.5	
		12 noon.	0.0542	0.0564	25.90	48.40	48.73	25.90	50.40	52.50	43.0	48.63
1	13	12 noon.	0.0542	0.0564							43.0	
		6 p. m.	0.0542	0.0564	25.90	45.20	101.55	25.90	46.75	125.11	25.5	48.63
2	14	6 a. m.	0.05335	0.0564							21.0	
		12 noon.	0.05335	0.0564	26.45	45.10	104.09	26.45	47.80	114.80	41.5	44.46
2	14	12 noon.	0.05335	0.0564							41.5	
		6 p. m.	0.05335	0.0564	26.45	45.10	108.38	26.45	47.10	108.11	26.5	44.46
3	15	6 a. m.	0.05335	0.0595							21.0	
		12 noon.	0.05335	0.0595	27.85	48.10	102.30	27.85	51.50	110.68	43.0	44.75
3	15	12 noon.	0.05335	0.0595							43.0	
		6 p. m.	0.05335	0.0595	27.85	46.75	131.40	27.85	46.90	138.44	27.0	44.75
4	16	6 a. m.	0.05335	0.0595							21.0	
		8 a. m.	0.05335	0.0595	27.85	52.85	39.56	27.85	54.10	30.50	35.0	67.04
4	16	8 a. m.	0.05335	0.0595							35.0	
		10 a. m.	0.05335	0.0595	27.85	52.70	43.95	27.85	53.70	46.07	36.5	67.04
4	16	10 a. m.	0.05335	0.0595							36.5	
		12 noon.	0.05335	0.0595	27.80	52.90	38.23	27.80	53.30	41.08	40.5	67.04
4	16	12 noon.	0.05335	0.0595							40.5	
		2 p. m.	0.05335	0.0595	27.85	52.30	47.01	27.85	53.30	41.60	43.0	67.04
4	16	2 p. m.	0.05335	0.0595							43.0	
		4 p. m.	0.05335	0.0595	27.85	52.90	38.35	27.85	53.00	51.30	37.0	67.04
4	16	4 p. m.	0.05335	0.0595							37.0	
		4 p. m.	0.05335	0.0595	27.85	53.20	35.10	27.85	54.00	35.54	26.0	67.04
5	17	6 a. m.	0.05335	0.0595							21.0	
		12 noon.	0.05335	0.0595	27.75	45.75	116.79	27.75	49.40	117.92	39.0	43.35
5	17	12 noon.	0.05335	0.0595							39.0	
		6 p. m.	0.05335	0.0595	27.75	46.40	104.60	27.75	47.80	112.39	26.0	43.35
7	19	6 a. m.	0.05335	0.0595							23.5	
		12 noon.	0.05335	0.0595	27.70	47.60	107.92	27.70	48.80	101.62	40.0	32.50
7	19	12 noon.	0.05335	0.0595							40.0	
		6 p. m.	0.05335	0.0595	27.75	47.20	107.59	27.75	48.40	112.15	27.0	32.50
0	20	6 a. m.	0.05335	0.0595							21.5	
		12 noon.	0.05335	0.0595	27.75	47.80	95.87	27.75	52.70	92.10	38.5	48.10
0	20	12 noon.	0.05335	0.0595							38.5	
		6 p. m.	0.05335	0.0595	27.70	46.80	100.52	27.70	49.65	102.44	26.0	48.10
1	21	6 a. m.	0.05335	0.0595							21.0	
		12 noon.	0.05335	0.0595	27.70	47.65	103.91	27.70	50.80	106.62	44.0	48.63
1	21	12 noon.	0.05335	0.0595							44.0	
		6 p. m.	0.05335	0.0595	27.70	47.90	105.41	27.70	50.30	106.91	28.5	48.63
0	22	6 a. m.	0.05335	0.0595							21.0	
		12 noon.	0.05335	0.0595	27.70	48.20	109.59	27.70	52.10	111.85	42.0	48.10
0	22	12 noon.	0.05335	0.0595							42.0	
		6 p. m.	0.05335	0.0595	27.70	48.40	126.84	27.70	50.90	128.27	28.0	48.10

Table I shows the results of the titrations of the samples of barium hydroxide from the experiment cylinder and from the check. It also gives the normalities of the solution used, the temperature of the air in the cylinder, and the volume of the air present in the tank at half-day (or two-hour) intervals during the progress of the work.

Table II shows the hourly variations in the rate of photosynthesis of sugar cane on March 16, 1919, as indicated by the number of grams of carbon dioxide absorbed per square meter of leaf surface per hour during the two-hour periods of the day. The leaf used in the test is number 4; therefore, there were three younger and three older leaves on the plant. The temperature at the beginning and at the end of each test was taken during the day. The interval between each pair of tests was about seven minutes.

TABLE II.—*Hourly variations in the rate of photosynthesis of sugar cane on March 16, 1919, as shown by the number of grams of CO_2 absorbed per square meter of leaf surface per hour during the two hour periods throughout the day.*

Period.	CO_2 absorbed per sq. m. per hour.	Temperature in cylinder.
a. m.	*gm.*	*°C.*
6:00 to 8:00	0.31	21.0° to 35.0°
8:00 to 10:00	0.60	35.0° to 36.5°
10:00 to 12:00	0.31	36.5° to 40.5°
p. m.		
12:00 to 2:00	0.32	40.5° to 43.0°
2:00 to 4:00	0.55	43.0° to 37.0°
4:00 to 6:00	0.43	57.0° to 26.0°

Remarks: Hazy from 8:30 a. m. to 9:15; 9:30 a. m. to 9:55 and from 10:05 a. m. to 10:10. Bright and windy from 11:00 a. m. Tips of leaves were observed to roll up at 11:10 a. m. Leaves were wide open at 2:30 p. m.

Since the values given in the second column of Table II represent amounts of carbon dioxide per hour, the amounts absorbed during two-hour periods may be obtained by multiplying the values in question by two.

The temperature in the cylinder showed a marked rise from 6:00 a. m. to 2:00 p. m., after which it began to fall reaching 26° C. at 6:00 p. m.

Table III presents data giving the rate of photosynthesis of sugar cane as shown by the number of grams of carbon dioxide absorbed per square meter of leaf surface per hour, during six-hour periods in the morning and in the afternoon. This table also gives the mean amount of carbon dioxide absorbed per hour during the twelve-hour period of the day. The intervals between the morning and the afternoon tests were about fourteen minutes; therefore, the period of each test was approximately seven minutes less than six hours; that is, five hours and fifty-three minutes. During this interval the baryta tubes and the wash bottles were changed, and the temperature, pressure, and water level readings were taken.

TABLE III.—*Rate of photosynthesis of sugar cane as shown by the number of grams of CO_2 absorbed per square meter of leaf per hour during six-hour periods in the morning and in the afternoon, and the mean amount of CO_2 absorbed per hour during the 12-hour periods during the day.*

Date.	Leaf[a] number.	A. M.		P. M.		Total CO_2 absorbed per hour during 12 hours.
		CO_2 absorbed.	Mean temperature in cylinder.	CO_2 absorbed.	Mean temperature in cylinder.	
March		*gm. per hr.*	*°C.*	*gm. per hr.*	*°C.*	*gm. per hr.*
11	2	.58	33.5	.25	35.5	.41
12	4	.74	32.3	.27	35.0	.51
13 [b]	1	.55	32.3	.79	34.3	.67
14	2	.92	31.3	.52	34.0	.72
15	3	1.05	32.0	.17	35.0	.61
16	4	.41	27.9	.43	31.3	.42
17	5	1.01	30.0	.56	32.5	.79
19 [c]	7	.27	31.8	.56	33.5	.41
20 [d]	0	1.12	30.0	.73	32.3	.93
21	1	.81	32.5	.61	36.3	.71
22	0	.99	31.5	.63	35.0	.81

a The leaves are numbered as follows: Leaf 1 was the youngest leaf at the beginning of the experiment. Leaf 2 was older than Leaf 1 and just below Leaf 1 on the stem. Leaves 3, 4, 5, and 7 are designated by the same method, Leaf 7 being the oldest. No test was made on Leaf 6, due to the fact that it was destroyed by wind before the tests were made.

b Hazy from 7:30 a. m. to 9:10.

c Hazy from 7:30 a. m. to 8:40; 8:55 a. m. to 9:35; 10:00. a. m. to 11:20. Cloudy from 2:00 p. m. to 2:35.

d This leaf appeared during the progress of work.

DISCUSSION OF THE RESULTS

It may be seen from Table II that the rate of photosynthesis was lower during the period from 10 a. m., to 2:00 p. m. than during the preceding period. A possible explanation of this phenomenon may be found in a decreased water content of the leaf during the period from 10:00 a. m. to 2:00 p. m. At 2 p. m. the temperature and light intensity had reached maximum values for the day. The tip of the leaf was observed to roll up after 11:10 a. m., and it unrolled again at 2:30 p. m. Although no attempt was made in the present experiment to measure the transpiration of the leaf, it is generally agreed that the higher the temperature and the greater the light intensity, the more rapid the rate of transpiration and the rate of absorption. Since there was no rain and no water was applied during this day, the water supply in the soil probably either remained constant or decreased, although no measurement was made of soil moisture. The transpiration rate probably exceeded the rate of absorption. This would result in a decreased water content of the leaf and would explain its rolled condition, which should influence photosynthesis. When the cells are turgid, the stomata are widely open, and thus allow CO_2 to enter readily.

It can also be seen from Table II that the rate of photosynthesis is highest from 8 a. m. to 10. Between the hours 8:30 a. m. and 9:15 and between 9:30 a. m. and 9:55 the weather was hazy. Although the period from 8 a. m. to 10 was hazy most of the time, nevertheless the test showed that the intake of CO_2 was most rapid during this period.

The probable explanation of the increase in the rate from 2:00 p. m. to 4:00 is that the leaf regained turgidity, and that this accelerated the rate of photosynthesis. The temperature fell from 43°C. at 2:00 p. m. to 37°C. at 4. It seems

probable that during this period the rate of transpiration was less than the rate of absorption. Evidence to support this assumption is furnished by the fact that the leaf had unrolled by 2:30 p. m.

From Table III it may be seen that all the half-day tests, except those on March 13, 16, and 19, show that the leaves exhibited greater photosynthesis activity in the morning than in the afternoon. This is probably due to the fact that during the middle of the day there is a general decrease in the moisture content of the leaves. Evidence that such a decrease took place is furnished by the rolling of the tips of the leaves, both inside of the cylinder and outside. The probable cause of the variations of Leaf 1 on March 13, Leaf 4 on March 16, and of Leaf 7 on March 19, is to be found in the weather conditions on those days. On March 13 the weather was hazy from 7:30 a. m. to 9:10. During this time the rate of photosynthesis was probably high, according to the two-hour tests made on March 16. The same conditions occurred on March 16 with Leaf 4 and on March 19 with Leaf 7. During the morning test on this leaf, the sky was hazy from 7:30 a. m. to 8:40; 8:55 a. m. to 9:35; and 10:30 a. m. to 11:20. In the afternoon the sky was cloudy from 2:00 p. m. to 2:35. All these tests seem distinctly to demonstrate that on clear days leaves are more active in the morning than in the afternoon.

There is a marked variation in the rate of photosynthesis in the different stages of maturity of the different leaves. Leaf 0 shows the highest rate. Two tests were made on this leaf, on March 20 and 22. Both tests showed a high rate, 0.93 grams per square meter being the hourly rate for March 20, and 0.81 grams per square meter per hour for March 22. Leaf 1 had a mean rate of 0.69 for the two tests made on March 13 and 21. Leaf 2 had an average of 0.57 for March 11 and 14. There was only one test made on Leaf 3, and it gave a rate of 0.61 grams per square meter per hour on March 15. The two tests which were made on Leaf 4 gave a mean value of 0.47 grams per square meter per hour. One test made on Leaf 5 gave a rate of 0.79 for March 17. This is a higher rate than was observed for any other leaf, except Leaf 0. Leaf 7, on March 19, showed a low rate, this being 0.41 grams per hour per square meter of leaf surface, and an equally low rate was obtained in the test on Leaf 2 on March 11 which amounted to only 0.41. This indicates the variability of the leaves at different stages of maturity of a single plant. The same leaf may exhibit a variation in its rate of photosynthesis. Leaf 2, for instance, had a rate of 0.41 grams on March 11, and a rate of 0.72 on March 14. This is shown also by Leaf 0, which on March 20 had a rate of 0.93 and on March 22, a rate of 0.81. From the data here available, it is impossible to determine the cause of these variations.

Although there is some fluctuation in the rate of photosynthesis in the different stages of maturity and in the same leaves on different days, it may be deduced from the results here presented that the rate of photosynthesis is in general highest when the leaf is younger, and that the rate decreases as the leaf grows older.

It has been noted previously that high light intensity was probably partly responsible for the decreased rate of photosynthesis in the afternoon, as compared with the rate in the morning. Very high intensity of light causes a rapid loss of water from the leaves, and the loss of water results in the rolling of the tips and probably the closing of the stomata. The environmental conditions, therefore,

have an indirect effect upon photosynthesis, unless the plant is sufficiently supplied with moisture to maintain the turgidity of the cells of the leaves. It has of course been known that light has also a direct effect upon photosynthesis. This process is dependent upon light as a source of energy, and reductions in light intensity may be accompanied by lowered rates of photosynthesis.

A test was made on the respiration of Leaf 3 from 6 p. m. of March 10 to 6 a. m. of March 11; and this gave a total of 4:19 grams of CO_2 per square meter of leaf surface as compared with 7.30, the total gain by photosynthesis of the same leaf on March 15. Another test was made on the respiration of Leaf 2 from 6 p. m. on March 11 to 6 p. m. on March 12. The test gave a total respiration of 1.80 grams of CO_2 per square meter of Leaf surface, and the same leaf gave a total gain by photosynthesis of 4.97 on March 11 for the same length of time. These two tests indicate rather distinctly that the rate of respiration was as much as one third or one half of the rate of photosynthesis.

CONCLUSIONS

1. The rate of photosynthesis decreased from 10 a. m. to 4 p. m.
2. The leaves were most active from 8 a. m. to 10.
3. The very young leaves were found to be most active, and the activity was found to decrease as the leaves became older.
4. It was found that the leaves were more active in the morning than in the afternoon.
5. The rate of respiration was apparently less than one half that of photosynthesis.
6. High intensity of light probably had an indirect relation to the rate of photosynthesis, and tended to decrease photosynthetic activity.
7. The rolling of the tips of the leaves appeared to accompany a decrease in the rate of photosynthesis.

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A PRELIMINARY SURVEY OF THE COMPARATIVE COSTS OF DIFFERENT METHODS OF HARVESTING RICE[1]

By ANGEL A. AFRICA

ONE PLATE

The rice problem is particularly important in the Philippine Islands because for many years past it has been necessary to import rice from other regions in order to supplement the inadequate local production. The problem became so serious during the past year that the Government found it necessary to place arbitrary price regulations upon the sale of rice.

The chief reasons given for the local importation of rice from other countries are: (1) unknown and fluctuating total cost of production; (2) labor cost, including systems of tenantry, which is still an unknown though probably adverse factor; (3) poor distribution. Harvesting, one of the most expensive steps in the production of rice, is done chiefly by hand in the Philippines. In most of the rice-growing regions the harvesters secure a share of the rice in payment for their work, which varies from one tenth to as much as one half of the quantity harvested.

No record of a definite study of the methods and cost of harvesting rice in the Islands has been found. Apostol (1) described two methods of harvesting rice in this country. These methods depend upon the variety of rice to be harvested, as to whether it is bearded or beardless. "For bearded varieties a hand instrument, having a wooden handle about 15 centimeters long and 2.5 centimeters wide, with a blade about 10 centimeters in length, sharpened on one edge, and fastened crosswise in a cut made at a point about 6 centimeters from the large end of the handle is used. The instrument is held in the right hand, with the blade between the first two fingers. To do the cutting, the fingers are extended and one or more straws are gathered in and drawn against the cutting edge by closing the fingers."

According to Apostol (1), straws about 25 centimeters long are left with the heads. After removing all the adhering leaves, the rice is tied up near the heads with bamboo "slatch" into bundles about seven centimeters in diameter. "Six of these bundles are called *manojitos*, *quinis*, or *bulsac*, and grouped in larger bundles, are known as *manojos* or *pungos*." After being cured, the rice is sold, stored in granaries, or sent to the mill for hulling.

In harvesting awnless, or beardless rice, a sickle-like instrument having a wooden V-shaped handle and a blade about 20 centimeters long and 3 centimeters wide is used. "The blade is slightly curved toward the cutting edge, and fixed at an angle in the handle about 15 centimeters from the end, just above the grip." With the sickle in the right hand, 20 to 50 stalks are caught, and by twisting a little the stalks are drawn together and caught by the left hand. Then the instrument is disengaged, and the stalks are cut about 30 centimeters below the heads. The cut crop is tied into bundles about 15 centimeters in diameter,

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[1] Thesis presented for graduation from the College of Agriculture, No. 112; Experiment Station contribution No. 34.

which are left in the fields to dry, and which in the evening are taken to a place where they can be cured. After curing, the crop is shocked in order to prevent the grains from being destroyed by excessive sunshine and showers (1).

Harvesting is done on a share basis in some localities, but in other places the harvesters are paid so much a day with subsistence. Subsistence commonly includes morning and noon meals. When harvesting is done on a share basis, the harvesters usually get from one eighth to one fourth of the amount harvested (1).

In the Sacramento Valley, California (2), the twine binder is used in harvesting rice. The crop is bound into sheaves, which are put in round shocks, strongly built, to protect the grain from the rain and the sun.

Reaping machines are generally used in Louisiana and Texas (3), although in other rice-growing sections where the use of such machines is not practical the sickle is used. The cutting is made at a distance of from 6 to 12 inches above the ground. The cut crop is bound into bundles and put in shocks.

Threshing rice in the Islands is done mostly by men and animals, Apostol (1) describes two methods of threshing rice; namely, flailing, and treading. "In some places the straw end of the bundle is fastened between two wooden sticks about 45 centimeters to 50 centimeters long, which are tied together by a piece of rope about 8 centimeters from one end, and the heads are then beaten against a hard board." Treading by men or animals is the most common method (2).

When carabaos are used, four or five animals are tied to a pole around which the unthreshed rice is placed on buri mats. The animals are driven around the pole, and the grain is trodden under their feet (1).

In the United States (2) steam threshers have come into use, and that country is at present the most advanced in the use of rice threshing machines. These threshers are largely used in California, Louisiana, and Texas. The chief objection to the use of steam threshers lies in the fact that a considerable amount of grain is lost through breakage.

The object of this paper is to present a description of the more extensively used methods of hand-harvesting of rice in the Philippine Islands, together with such data as will, within the limits of the survey, establish cost relatives to area and yield and indicate the labor wage received by the harvesters under the different methods.

The data, for purposes of eliminating inaccuracies due to temporary or local causes, have been spread over the following localities and seasons: Lipa, Batangas, September and October, 1919; Rosario, Batangas, October and November, 1919; Bocawe, Bulacan, December, 1919; Sta. Maria, Bulacan, December, 1919; Bulacan, Bulacan, December, 1919; Guiguinto, Bulacan, December, 1919; Jaen, Nueva Ecija, December, 1919; Cabanatuan, Nueva Ecija, December, 1919.

IMPLEMENTS USED IN HARVESTING

Samples of the different implements used in harvesting rice in the Philippine Islands were brought to the College for study. The following are the implements studied:(1) the *yatab* or *pañgani*(Tagalog) (Fig. 1, Plate I); (2) the sickle or *lilik* (Tagalog) (Fig. 2, Plate I); (3) the *lincao* (Tagalog) (Fig. 3, Plate I); (4) the *palót* (Tagalog) (Fig. 4, Plate I); (5) the *palót* (Pangasinan) (Fig. 5. Plate I); and (6) the *gamlang* (Pangasinan) (Fig. 6, Plate I).

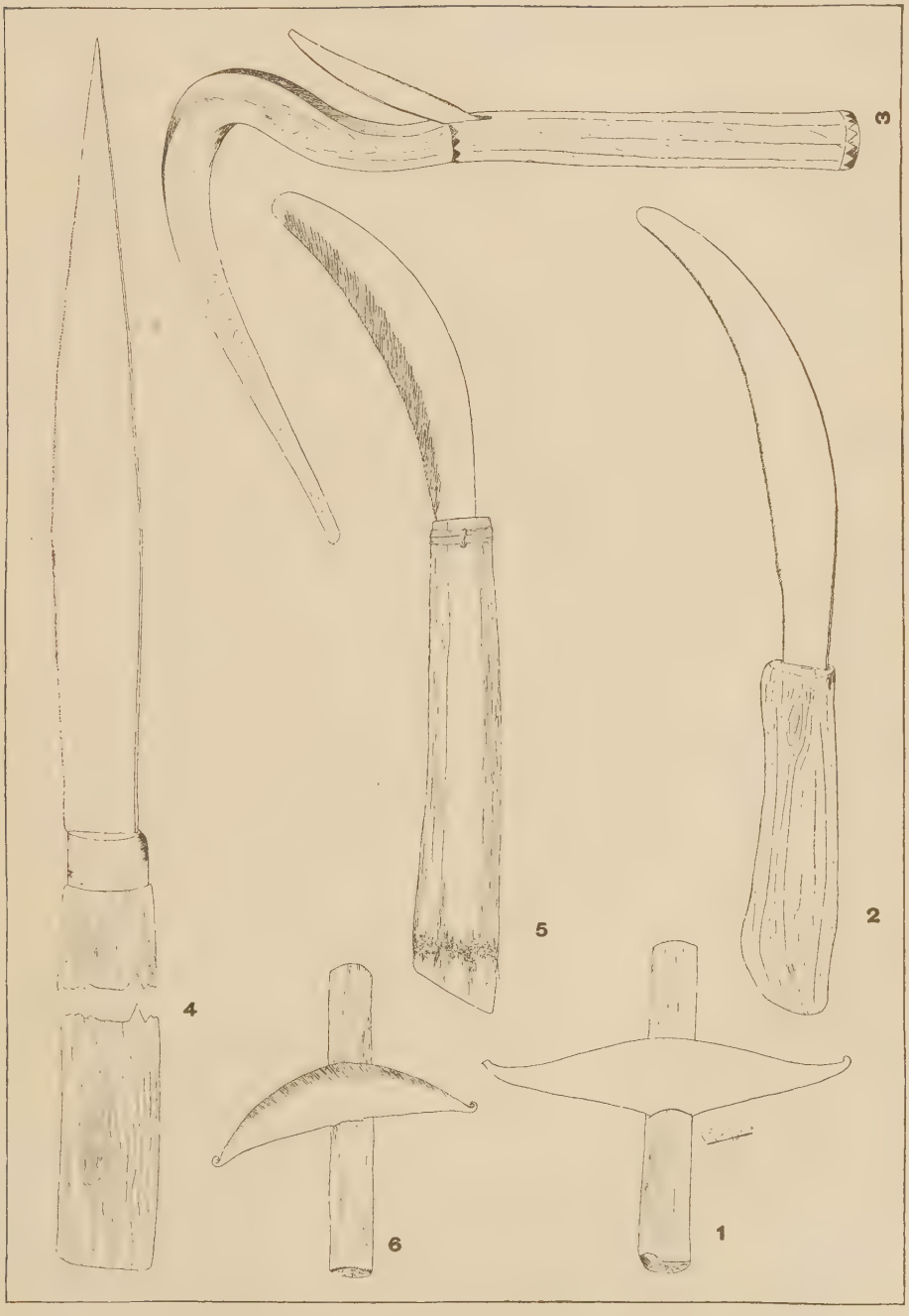

PLATE I. HAND IMPLEMENTS USED IN HARVESTING RICE

The *yatab* or *pañgani* (Fig. 1, Plate I) is a handy instrument with a blade about 14.5 centimeters long, 3.5 centimeters wide at the widest part, fastened in a cut at about the middle of the handle. The handle is usually made of a cylindrical piece of wood about 2 centimeters in diameter and about 13 centimeters long. The length and diameter of the handle are varied to suit the convenience of the owner.

The *lilik*, or sickle (Fig 2, Plate I) is another implement used in cutting rice. The blade is about 20 centimeters long and about 2.5 centimeters wide at the middle. It is serrated and is slightly curved toward the cutting edge. The handle is usually made of wood, but bamboo is sometimes used.

The *lincao* (Fig. 3, Plate I) is an implement with a wooden hook-like handle. The blade attached to the handle is similar to that of the *lilik* (Fig. 2, Plate I). The blade is fixed at a certain angle in the handle about 30 centimeters from the end. The size of the handle and the fixing of the blade vary in different localities.

The *palót* (Fig. 4, Plate I) has the form of a bolo. The blade is straight and is pointed at the tip. The blade is serrated to the point and is about 6 centimeters long, and 3.5 centimeters wide. The handle is usually made of wood and is about 16 centimeters long and 3 centimeters in diameter.

The *palot* (Fig. 5, Plate I) is another form of sickle; its blade is curved more towards the cutting edge than that of the *lilik* (Fig. 2, Plate I). The blade is also serrated, but the teeth are arranged differently from those of the *lilik*. The blade is 15 centimeters long, 3 centimeters wide, and is attached to a wooden or bamboo handle about 18 centimeters long. The length of the handle varies in different localities.

The *gamlang* (Fig. 6, Plate I) is very similar to the *yatab* (Fig. 1, Plate I) except that the former is smaller, and its blade is only lightly serrated. The blade, which is about 11 centimeters long and 2.5 centimeters wide, is fixed in the middle of a wooden handle about 12.5 centimeters long and 1.5 centimeters in diameter. The size and length of the handle vary.

METHODS OF HARVESTING

To get the necessary data and information regarding the methods of harvesting, the writer made trips to the towns already mentioned. In the towns of Los Baños, Lipa, and Rosario, personal observations were made. The total time spent, the total number of laborers, and the actual yield per unit were recorded. The data and information from other towns were obtained from farmers who make observations and keep records of the expenses involved in the different operations of producing rice.

In Batangas province the implements commonly used in cutting rice are the *yatab*, or the *pangani*, and the *lilik*. The *yatab* is used largely in cutting early varieties of rice, such as *Dumali*, *Kinanda*, and *Malagkit*. These varieties require care in handling, for their grains do not adhere to the spikelets as firmly as do those of the late varieties. The implement is held in the right hand with the blade between the first two fingers, or the third and fourth, as the worker wishes. The heads are cut one by one. They are caught by the left hand, and by extending the fingers of the right hand and drawing the head against the blade, the rice is cut. The cutting is usually made just below the last node of the spikelet, or at about from 5 to 10 centimeters below the head. The cut crop is put in a bamboo basket, termed *takuyan*, which each laborer carries strapped by a leather belt around his waist.

After filling the baskets the contents are placed on buri mats. Piles of rice heads on the mats are called *buntun.*

The *lilik* (sickle) is used in cutting the late-maturing varieties. The stalks of rice are caught by the left hand and are cut by means of the sickle held in the right hand. The stalks are usually cut at a distance of about 60 centimeters above the ground; this distance, however, varies with the height of the plants. After the cutting is done, the rice stalks are gathered and piled in heaps called *sipok.* Threshing usually follows; but sometimes the laborers leave these *sipok* on the fields from one to two weeks before they are threshed. This is done, however, only in times when the laborers find it necessary to work in other fields.

Threshing is done by the feet on buri mats or on sawali. Buri mats are widely used because they can be carried from one place to another with greater ease than the sawali ones. The unthreshed rice is scattered on the mats and is trodden upon by the feet. The straw is separated from the grain by hand-picking and by winnowing.

In Laguna, the *yatab, lincao,* and the *lilik* are the implements used in cutting rice. The *yatab* is used for the early varieties. The *lincao* and the *lilik* are used in cutting paddy, or lowland rice. The methods of handling the *lilik* in Laguna are similar to those of Batangas. When the *lincao* is used, the laborers catch the rice stalks by means of the hook-like projection of the handle; and by twisting the instrument the stalks are gathered into the left hand, after which the cutting is done with the aid of the attached blade. The cut crop is left scattered in the fields and in the afternoon is gathered and piled in heaps called *sipok.*

Threshing is done immediately after gathering the cut crop. Men and women do the threshing with their feet. The unthreshed rice is laid on buri or sawali mats and is tramped upon by the feet The straw and chaff are separated from the grains by hand-picking and by winnowing.

In the province of Bulacan, rice is cut by means of the *lincao* and the *palot.* When the *lincao* is used, the laborers sometimes "fell" the standing crop flat to the ground in one direction with the aid of long bamboo poles. This is done to facilitate the cutting. The principle of cutting is the same as in Laguna; but in Bulacan, the cut crop is tied into bundles about five centimeters in diameter. These bundles are left standing in the fields with the heads down for two or three days for the purpose of drying. Then the bundles are gathered and piled on the dikes in heaps called *timbon* or *sipok.* The bundles are then left in the fields for two or three weeks to dry. The length of time depends, however, upon the condition of the weather. They are then piled in larger heaps called *mandalá.* The base of the *mandalá* is usually round in shape. In making a *mandalá* the sheaves are stacked with the heads up. The first piling serves as the base, and the succeeding sheaves are piled with the straw ends out. The top of the stack is drawn into a cone, and the straw ends of the top layers are bound together to serve as a cap.

The *palót* is commonly used in the town of Bulacan, Bulacan. To do the cutting, the stalks are caught by the left hand and are cut with the implement held in the right hand. The height of cutting is from 30 to 50 centimeters above the ground. This length, however, is not definite, depending largely upon the height of the plants. The cut crop is bound into sheaves and handled in the same manner as under the *lincao* method.

In Bulacan threshing is done by men and animals. The rice is placed on buri mats and is threshed by men who tread upon it. Occasionally, however, animals are used. When this is the case, a pavement of carabao dung is first constructed near the *mandalá*. For its construction, rice straw is first scattered over the selected place, the thickness of the straw pile depending upon the judgment of the laborers. When the desired amount has been scattered, a sticky mixture of carabao dung and water, sufficient to get thickness of at least two centimeters, is poured over the place.

In the center of this threshing floor the animals are tied to a pole. The unthreshed rice is scattered on the floor, and the animals are driven around the pole. The number of animals used varies, depending upon the amount of grain to be threshed. Threshing is usually done at night some time during the months of February, March, and April.

In Nueva Ecija the methods of harvesting are similar to those used in Bulacan. The implements commonly used are the *lincao* and the *palót*. In some parts of the province, as in Bulacan, the cut crop is not tied into small bundles, but is left untied in the fields to dry. After a few days it is gathered, bound into bundles, about 30 centimeters in diameter, and piled in *sipok*. After a few weeks the bundles are piled in *mandalás*.

Threshing in Nueva Ecija is sometimes done by steam threshers. Carabaos are preferred in some places because a considerable portion of the grain is broken when steam threshers are used. Men seldom do the threshing.

METHODS OF PAYMENT

The methods of payment for harvesting and threshing vary in the different localities. In Batangas the harvesting is done on a share basis of from one sixth to one half of the amount harvested, and the laborers are held responsible for everything from cutting to threshing. They bring with them their own implements and whatever else they need. The farmer only supervises their work.

In the towns of Lipa, and Rosario, Batangas, one fourth of the crop is usually given to the workers. However, when the harvest is plentiful and there is a scarcity of laborers as much as half of the crop is given. The producer loses a great deal of his crop in giving the share to the laborers; because if the time spent by the producer and the harvesters be compared, the advantage, of course, will be on the harvesters' side, for they receive nearly as much as the farmer. This loss on the part of the farmer could be reduced if a method which would lessen the amount of labor were found. The producers as well as the harvesters would be benefited thereby.

In Laguna, harvesting is done on a share basis of from one tenth to one fourth of the crop. As in Batangas, the same group of laborers accomplish the entire process, and in payment for their work they are given a share of the crop. In Calamba, Laguna, the laborers do all the work from cutting to cleaning the grain and are given one eighth of the quantity harvested by them. In Bay, Laguna, the same method of paying the labor cost is employed, but one sixth instead of one eighth is given.

In Bulacan and Nueva Ecija a different method of payment is used. There are places where the laborers are paid a certain amount, varying from ₱0.60 to as much as ₱2.00 a day, with subsistence. For cutting, gathering and piling,

the usual wage per man is ₱1.00 with subsistence. For piling the sheaves in *mandalá* the laborers get from ₱1.50 to ₱2.00 a day with subsistence because they use their own animals, carts, and sleds.

In addition to the above mentioned pay, in some places in Nueva Ecija the laborers are allowed to carry away with them a large bundle of rice, which when threshed will give from four to six gantas of palay. Some laborers make a contract per hectare, while others are paid according to the number of bundles they harvest in a day.

Threshing in Bulacan and Nueva Ecija is done either on a share basis or by giving a certain percentage to the laborers. The usual amount given is from two to two and one half gantas for every cavan threshed. In some cases the owner of the animals used is paid a certain amount a night, which varies from three to seven gantas for a night's work of one carabao. The laborers do all the work and get their shares in cleaned rice. When steam threshers are used the amount given to the owner of the machine varies from eight to nine per cent of the amount threshed.

SURVEYS AND RESULTS

Table I shows the labor cost of harvesting and threshing rice by the Laguna *yatab* method. The data were secured from cultures on the Experiment Station of the College of Agriculture, University of the Philippines. The data were collected from actual observation.

The women who did the larger part of the work were paid at the rate of 80 centavos for a day of 9 hours, or 8.88 centavos per hour. The few men who were employed were paid at the rate of 12 centavos per hour. The maximum harvest cost in this system fell to unit number 8 at ₱61.1498, and the minimum per hectare to unit number 6 at ₱21.8378. But considering the harvest cost per cavan, which for reasons of variance of soil and other culture conditions was found to be a far more reliable cost relative than the cost per hectare, the maximum cost fell to unit number 8 at ₱1.5555 and the minimum to unit number 6 at ₱0.6943. The average harvest cost per hectare was ₱40.1392 and the average per cavan was ₱1.0793.

Table II shows the labor cost of harvesting and threshing rice by the Batangas sickle method. The data were obtained from the towns of Lipa and Rosario, province of Batangas, through personal observation during the harvest season in those regions in the year 1919.

In these towns men, women, and children did the harvesting and were given one fourth of the amount harvested in payment for their work. The maximum harvest cost per hectare in this system fell to unit number 8 at ₱69.2471, and the minimum per hectare to unit number 12 at ₱31.185. In this system the harvest cost per cavan was ₱1.875. The amount was the same in every unit because the laborers were given the same share for every cavan harvested. The average harvest cost per hectare was ₱51.8151, and the average cost per cavan was ₱1.875.

Table III shows the labor cost of harvesting and threshing rice by the *palót* method. The data were secured by correspondence with farmers of the towns of Bulacan and Guiguinto, Bulacan, and of the towns of Cabanatuan and Jaen, Nueva Ecija.

TABLE I.—*Labor cost of harvesting and threshing rice by the Laguna yatab method.*

Serial No. of units.	Area.	Yield.	Laborers.			Time.			Hourly cash wages.			Wage cost.			Cost per hectare.	Cost per cavan.
			Men.	Women.	Total.	Men.	Women.	Total.	Men.	Women.	Average.	Men.	Women.	Total.		
	Ha.	*Cavans.*	*No.*	*No.*	*No.*	*Hr.*	*Hr.*	*Hr.*	*Pesos.*	*Pesos.*	*Pesos.*	*Pesos.*	*Pesos.*	*Pesos.*	*Pesos.*	*Pesos.*
1	0.0546	2.533	1	6	7	3.25	4.00	27.25	0.12	0.0888	0.1044	0.39	2.1333	2.5233	46.2142	0.9961
2	0.0546	1.570	1	8	9	2.00	2.50	22.00	0.12	0.0888	0.1044	0.24	1.7777	2.0177	36.9542	1.2214
3	0.0546	1.234		6	6		2.4166	14.50		0.0888	0.0888		1.2888	1.2888	23.6043	1.0444
4	0.1872	7.133		6	6		10.00	60.00		0.0888	0.0888		5.3333	5.3333	28.4898	0.7476
5	0.0407	1.60		3	3		8.00	24.00		0.0888	0.0888		2.1333	2.1333	52.4152	1.3333
6	0.0407	1.28		2	2		5.00	10.00		0.0888	0.0888		0.8888	0.8888	21.8378	0.6943
7	0.0324	1.10		2	2		8.00	16.00		0.0888	0.0888		1.4222	1.4222	43.8950	1.2929
8	0.0407	1.60		4	4		7.00	28.00		0.0888	0.0888		2.4888	2.4888	61.1498	1.5555
9	0.1125	4.296		6	6		7.50	45.00		0.0888	0.0888		4.0000	4.0000	35.5555	0.9310
10	0.1125	4.712		6	6		11.25	67.50		0.0888	0.0888		6.0000	6.0000	53.3333	1.2723
11	0.1125	4.24		7	7		7.7142	54.00		0.0888	0.0888		4.8000	4.8000	42.6666	1.1320
12	0.1125	5.48		7	7		6.4285	45.00		0.0888	0.0888		4.0000	4.0000	35.5555	0.7299
Totals	0.9555	36.778	2	63	65	5.25	79.8092	1413.25	0.24	1.0656	1.0968	0.63	36.2662	36.8962	481.6712	12.9517
Average	0.0796	3.0646	0.166	5.25	5.4166	0.4-375	6.6507	4.43-375	0.02	0.0888	0.0914	0.0-525	3.0221	3.0746	40.1392	1.0793

TABLE II.—*Labor cost of harvesting and threshing rice by the Batangas sickle method.*

Serial No. of unit.	Area.	Yield.	Laborers.				Time.		Wages in commodity.					Cost per hectare.	Cost per cavan.
			Men.	Women	Children.	Total.	Ave. per laborer.	Total.	Total share.	Market price per cavan.	Total value share.	Average value per laborer.	Average value per laborer per hr.		
	Ha.	*Cavans.*	*No.*	*No.*	*No.*	*No.*	*Hours.*	*Hours.*	*Cavans.*	*Pesos.*	*Pesos.*	*Pesos.*	*Pesos.*	*Pesos.*	*Pesos.*
1	0.3216	11.00	24	10	7	41	2.4085	98.95	2.75	7.50	20.625	0.5030	0.2088	64.1342	1.875
2	0.1827	5.60	8			8	3.9166	31.3333	1.40	7.50	10.50	1.3125	0.3357	57.4712	1.875
3	0.3216	10.10	14			14	4.50	63.00	2.525	7.50	18.9375	1.3526	0.3005	58.8852	1.875
4	0.2336	7.00	16	3		19	1.5614	29.6666	1.75	7.50	13.125	0.6907	0.4424	56.1857	1.875
5	0.2441	8.40	38	12		50	0.78	39.00	2.10	7.50	15.75	0.3150	0.4038	64.5227	1.875
6	0.2214	5.60	10	7		17	2.0637	25.0833	1.40	7.50	10.50	0.50	0.2422	47.4254	1.875
7	0.43	10.00	35	11		46	1.2753	58.6666	2.50	7.50	18.75	0.4076	0.3191	43.6046	1.875
8	0.176	6.50	6	6		12	3.125	37.50	1.625	7.50	12.1875	1.0156	0.3250	69.2471	1.875
9	0.1386	4.40	24	14		38	0.6973	26.50	1.10	7.50	8.25	0.2171	0.3113	59.5238	1.875
10	0.1834	5.80	38	17		55	0.7818	43.00	1.45	7.50	10.875	0.1794	0.2295	59.2966	1.875
11	0.5519	15.80	26			26	4.1249	107.25	3.95	7.50	29.625	1.1394	0.2763	53.6782	1.875
12	0.6302	22.00	90	96	26	212	0.7676	162.75	5.50	7.50	41.25	0.1945	0.2534	65.4554	1.875
13	0.5848	15.00	28	32	16	76	1.9583	148.8333	3.75	7.50	28.125	0.3700	0.1889	48.0933	1.875
14	0.3546	6.00	38	36	12	86	0.5959	51.25	1.50	7.50	11.25	0.1308	0.2195	31.7258	1.875
15	0.481	8.00	28	24	10	62	0.8548	53.00	2.00	7.50	15.00	0.2419	0.2830	31.1850	1.875
16	0.8383	18.00	18	12	3	33	4.0454	133.50	4.50	7.50	33.75	1.0227	0.2528	40.2600	1.875
17	0.213	4.50	14	16	6	36	1.2361	44.50	1.125	7.50	8.4375	0.2343	0.1896	39.6126	1.875
18	0.51	15.50	30			30	3.4166	112.50	3.875	7.50	29.0625	0.9687	0.2835	56.9852	1.875
19	0.722	16.00	24			24	7.50	180.00	4.00	7.50	30.00	1.2500	0.1666	41.5512	1.875
20	0.3358	8.50	28	20		48	2.00	96.00	2.125	7.50	15.9375	0.3320	0.1660	47.4612	1.875
Totals	7.6746	203.70	537	316	80	933	47.6092	1552.0831	50.9250	150.00	381.9375	12.3778	5.3973	1036.3026	37.50
Ave.	0.2837	10.185	26.85	15.8	4	46.65	2.3804	77.6041	2.5462	7.50	19.0968	0.6188	0.2698	51.8151	1.875

TABLE III.—*Labor cost of harvesting*

Serial No. of unit.	Area.	Yield.	Laborers.			Time.		Wages in cash.							
			Men.	Women	Total.	Average per laborer.	Total.	Laborers.	Total time.	Total wages.	Average per laborer.	Average per laborer per day.	Laborers.	Total time.	
	Ha.	*Cavans.*	*No.*	*No.*	*No.*	*Days.*	*Days.*	*No.*	*Days.*	*Pesos.*	*Pesos.*	*Pesos.*	*No.*	*Days.*	*C*
1 a	0.2857	28	11	2	13	1.00	13	8	8	8.00	1.00	1.00	5	5	
2 a	1.70	100	51	2	53	1.8886	63	48	48	48.00	1.00	1.00	5	15	
3 a	0.2857	20	21		21	1.00	21	17	17	17.00	1.00	1.00	4	4	
4	0.2857	30	32		32	0.875	28	24	20	12.00	0.50	0.60	8	8	
5 a	0.2857	20	12	3	15	1.00	15	9	9	9.20	1.0222	1.0222	6	6	
6 a	1.00	60	25		25	1.00	25	20	20	20.00	1.00	1.00	5	5	
7 a	1.00	40	21		21	1.1904	25	16	20	24.80	1.55	1.24	5	5	
8 a	1.00	35	17		17	1.00	17	14	14	16.00	1.1435	1.1435	3	3	
9	1.00	60	40		40	1.25	50	30	30	30.00	1.00	1.00	10	20	
10 a	1.00	35	20		20	1.00	20	16	16	18.00	1.125	1.125	4	4	
Totals	7.8428	428	250	7	257	10.5040	377	202	202	203	10.3407	10.1307	55	75	6
Average	0.7842	42.8	25	0.7	25.7	1.0504	37.7	20.2	20.2	20.3	1.03407	1.01307	5.5	7.5	

aThe laborers used carabaos to thresh the rice.

TABLE IV.—*Labor cost of harvesting*

Serial No. of unit.	Area.	Yield.	Laborers.			Time.		Wages in cash.							
			Men.	Women	Total.	Average per laborer.	Total.	Laborers.	Total time.	Total wages.	Average per laborer.	Average per laborer per day.	Laborers.	Total time.	
	Ha.	*Cavans.*	*No.*	*No.*	*No.*	*Days.*	*Days.*	*No.*	*Days.*	*Pesos.*	*Pesos.*	*Pesos.*	*No.*	*Days.*	*Ca*
1 a	1.0	45	21		21	1.0	21	15	15	22.00	1.4666	1.4666	6	6	
2 a	1.0	55	39	3	42	1.0	42	33	33	33.00	1.00	1.00	9	9	
3 a	3.056	200	115	4	119	1.126	134	104	104	104.00	1.00	1.00	15	30	2
4	1.0	35	30	4	34	1.0	34	26	26	26.00	1.00	1.00	8	8	
5	2.0	100	100		100	1.4	140	80	80	90.00	1.125	1.125	20	60	
6	2.0	80	85		85	1.0	85	55	55	65.00	1.1818	1.1818	30	30	
7	2.0	100	48	8	56	3.0	168	40	120	120.00	3.00	1.00	16	48	
8 a	1.0	45	19		19	1.1578	22	13	16	16.00	1.2307	1.00	6	6	
9 a	1.0	50	29		29	1.0	29	23	23	27.00	1.1739	1.1739	6	6	
10 a	1.0	40	20		20	1.0	20	15	15	18.00	1.20	1.20	5	5	
Totals	15.056	750	506	19	525	12.6838	695	404	487	521.00	13.3780	11.1473	121	208	6
Average	1.5056	75	50.6	1.9	52.5	1.2683	69.5	40.4	48.7	52.10	1.3378	1.1147	12.1	20.8	

aThe laborers used carabaos to thresh the rice.

nd threshing rice by the palót method.

Wages in commodity.					Wages in subsistence.					Cost for the unit.	Cost per hectare.	Cost per cavan.
al e.	Market price per cavan.	Total value of share.	Average value per laborer.	Average value per laborer per day.	Laborers.	Total time.	Total value of subsist-ence.	Total value of subsistence per laborer.	Total value of subsistence per laborer per day.			
ns.	*Pesos.*	*Pesos.*	*Pesos.*	*Pesos.*	*No.*	*Days.*	*Pesos.*	*Pesos.*	*Pesos*	*Pesos*	*Pesos*	*Pesos*
2	7.50	46.50	9.30	9.30	8	8	6.40	0.80	0.80	60.90	213.1606	2.1750
44	7.50	160.80	32.16	10.72	48	48	38.40	0.80	0.80	247.20	145.4117	2.4720
12	7.50	23.40	5.85	5.85	17	17	13.60	0.80	0.80	54.00	189.0094	2.7000
5	7.50	18.75	2.3437	2.3437	24	20	16.00	0.6666	0.80	46.75	163.6331	1.5583
8	7.50	51.00	8.50	8.50	9	9	5.40	0.60	0.60	65.60	229.6114	3.2800
0	7.50	45.00	9.00	9.00	20	20	10.00	0.50	0.50	75.00	75.00	1.2500
0	7.50	30.00	6.00	6.00	16	20	20.00	1.25	1.00	74.80	74.80	1.8700
5	7.50	26.25	8.75	8.75	14	14	12.60	0.90	0.90	54.85	54.85	1.5671
6	7.50	57.00	5.70	2.85	30	30	6.00	0.50	0.50	93.00	93.00	1.5500
5	7.50	26.25	6.5625	6.5625	16	16	12.80	0.80	0.80	57.05	57.05	1.6300
66	75.00	484.95	94.1662	69.8762	202	202	141.20	7.6166	7.50	829.15	1295.5262	20.0524
466	7.50	48.495	9.4166	6.9876	20.2	20.2	14.12	0.7616	0.75	82.915	129.5526	2.0052

nd threshing rice by the lincao method.

Wages in commodity.					Wages in subsistence.					Cost for the unit.	Cost per hectare.	Cost per cavan.
al e.	Market price per cavan.	Total value of share.	Average value per laborer.	Average value per laborer per day.	Laborers.	Total time.	Total value of subsist-ence.	Total value of subsistence per laborer.	Total value of subsistence per laborer per day.			
ns.	*Pesos.*	*Pesos.*	*Pesos.*	*Pesos.*	*No.*	*Days.*	*Pesos.*	*Pesos.*	*Pesos.*	*Pesos.*	*Pesos.*	*Pesos.*
6	7.50	27.00	4.50	4.50	15	15	9.00	0.60	0.60	58.00	58.00	1.2888
5	7.50	41.25	4.5833	4.5833	33	33	19.80	0.60	0.60	94.05	94.05	1.7100
0	7.50	150.00	10.00	5.00	104	100.4	62.40	0.60	0.60	316.40	103.534	1.5820
5	7.50	26.25	3.2812	3.2812	26	26	15.60	0.60	0.60	67.85	67.85	1.9385
0	7.50	60.00	3.00	1.00	80	80	64.00	0.80	0.80	214.00	107.00	2.1400
0	7.50	60.00	2.00	2.00	55	55	55.00	1.00	1.00	180.00	90.00	2.2500
0	7.50	60.00	3.75	1.25	40	120	60.00	1.50	0.50	240.00	120.00	2.4000
5	7.50	33.75	5.625	5.625	13	16	9.60	0.7384	0.60	59.35	59.35	1.3188
0	7.50	30.00	5.00	5.00	23	23	13.80	0.60	0.60	70.80	70.80	1.4160
2	7.50	24.00	4.80	4.80	15	15	9.00	0.60	0.60	51.00	51.00	1.2750
3	75.00	512.25	46.5395	37.0395	404	487	318.20	7.6384	6.50	1351.45	821.584	17.3191
83	7.50	51.225	4.6539	3.7039	40.4	48.7	31.82	0.7638	0.65	135.145	82.1584	1.7319

In these regions harvesting was done mostly by men and women, but children were also employed. These laborers were paid a certain amount a day in cash, given subsistence, and a share of the harvest. The wages, value of subsistence, and amount of the commodity given to each laborer varied in the different localities. The maximum harvest cost per hectare in this system fell to unit number 5 at ₱229.6114, and the minimum per hectare to unit number 8 at ₱54.85. The maximum harvest cost per cavan fell to unit number 5 at ₱3.28 and the minimum to unit number 6 at ₱1.25. The average harvest cost per hectare was ₱129.5526, and the average per cavan was ₱2.0052.

Table IV shows the labor cost of harvesting and threshing rice by the *lincao* method. The data were secured, in the same manner as the data for Table III, from the towns of Bocawe and Sta. Maria, Bulacan, and Cabanatuan, Nueva Ecija.

Men, women, and children were employed in harvesting. The system of payment under this method was exactly the same described in the discussion of the *palót* method; that is, cash, share, and two-meal subsistence. The maximum harvest cost per hectare in this system fell to unit number 7 at ₱120.00, and the minimum per hectare to unit number 10 at ₱51.00. The maximum harvest cost per cavan fell to unit number 7 at ₱2.40, and the minimum to unit number 10 at ₱1.275. The average harvest cost per hectare in this system was ₱82.1584 and the average per cavan was ₱1.7319.

Table V shows the labor cost of harvesting and threshing rice by the Laguna sickle method. The data were secured by correspondence with farmers of Bay, Laguna.

In this region men, women, and children did the harvesting. The laborers were usually given one sixth of the amount harvested. The maximum cost per hectare in this system fell to unit numbers 1, 4, and 18 at ₱53.333, and the minimum cost per hectare to unit numbers 10 and 22 at ₱20.00. The harvest cost per cavan in this system was ₱1.3333. The amount was the same in all the units, because the laborers were given the same share for every cavan harvested. The average per hectare in this system was ₱35.0933, and the average per cavan was ₱1.3333.

Table VI shows the labor cost of harvesting and threshing rice by the Batangas *yatab* method. The data were secured through personal observation in the rice fields during the harvest season of 1919 in the towns of Lipa and Rosario, Batangas.

In these regions men, women, and children harvested the rice crop and were usually given one fourth of the amount harvested in payment for their work. The maximum harvest cost per hectare in this system fell to unit number 6 at ₱100.00, and the minimum cost to unit number 9 at ₱30.303. The harvest cost per cavan in this system was ₱2.50. This amount was the same for all the units because the laborers were given the same share for every cavan harvested. The average harvest cost per hectare was ₱59.4734 pesos and the average per cavan was ₱2.5.

DISCUSSION OF RESULTS

From a comparative study of the methods surveyed, several striking contrasts appear. In an analysis of the production cost figures, both the scale of the production, and the ratio between unit yield and unit area are found to affect the cost.

Table VII presents comparison of cost of harvesting for the several methods segregated into total-yield groups.

TABLE V.—*Labor cost of harvesting and threshing rice by the Laguna sickle method.*

Serial No. of unit.	Area.	Yield.	Laborers.	Time.		Wages in commodity.					Cost per hectare.	Cost per cavan.
				Average per laborer.	Total.	Total share.	Market per cavan.	Total value of share.	Average value per laborer.	Average value per laborer per day.		
	Ha.	*Cavans.*	*Number.*	*Days.*	*Days*	*Cavans.*	*Pesos.*	*Pesos.*	*Pesos.*	*Pesos.*	*Pesos.*	*Pesos.*
1	1.0	40	10	3.5	35	6.6666	8.00	53.3333	5.3333	1.5238	53.3333	1.3333
2	1.0	30	35	1.0	35	5.00	8.00	40.00	1.1428	1.1428	40.00	1.3333
3	1.0	25	25	1.0	25	4.1666	8.00	33.3333	1.3333	1.3333	33.3333	1.3333
4	1.5	60	20	3.5	70	10.00	8.00	80.00	4.00	1.1428	53.3333	1.3333
5	1.0	25	15	2.0	30	4.1666	8.00	33.3333	2.2222	1.1111	33.3333	1.3333
6	1.0	35	35	1.2857	45	5.8333	8.00	46.6666	1.3333	1.0369	46.6666	1.3333
7	2.0	50	20	4.0	80	8.3333	8.00	66.6666	3.3333	0.8333	33.3333	1.3333
8	2.0	35	20	2.5	50	5.8333	8.00	46.6666	2.3333	0.9333	23.3333	1.3333
9	1.0	25	10	2.0	20	4.1666	8.00	33.3333	3.3333	1.6666	33.3333	1.3333
10	1.0	15	10	2.0	20	2.50	8.00	20.00	2.00	1.00	20.00	1.3333
11	1.0	25	20	2.0	40	4.1666	8.00	33.3333	1.6666	0.8333	33.3333	1.3333
12	2.0	45	40	1.5	60	7.50	8.00	60.00	1.50	1.00	30.00	1.3333
13	2.5	50	20	4.0	80	8.3333	8.00	66.6666	3.3333	0.8333	26.6666	1.3333
14	1.0	35	15	2.0	30	5.8333	8.00	46.6666	3.1111	1.5555	46.6666	1.3333
15	1.0	30	10	2.0	20	5.00	8.00	40.00	4.00	2.00	40.00	1.3333
16	1.0	20	10	2.0	20	3.3333	8.00	26.6666	2.6666	1.3333	26.6666	1.3333
17	1.0	18	15	1.0	15	3.00	8.00	24.00	1.60	1.60	24.00	1.3333
18	1.0	40	20	2.5	50	6.6666	8.00	53.3333	2.6666	1.0666	53.3333	1.3333
19	2.0	50	10	5.5	55	8.3333	8.00	66.6666	6.6666	1.2121	33.3333	1.3333
20	1.0	30	10	3.5	35	5.00	8.00	40.00	4.00	1.1428	40.00	1.3333
21	1.5	35	15	2.5	37.5	5.8333	8.00	46.6666	3.1111	1.2444	31.1111	1.3333
22	1.0	15	10	2.0	20	2.50	8.00	20.00	2.00	1.00	20.00	1.3333
23	1.0	20	24	1.0	35	3.3333	8.00	26.6666	0.7619	0.7619	26.6666	1.3333
24	1.5	40	25	4.0	100	6.6666	8.00	53.3333	2.1333	0.5333	35.5555	1.3333
25	1.0	30	15	2.5	37.5	5.00	8.00	40.00	2.6666	1.0666	40.00	1.3333
Totals	32.0	823	470	60.7857	1015.0	137.1659	200.00	1097.3325	68.2485	28.9070	877.3326	33.3325
Average	1.28	32.92	18.8	2.4311	41.8	5.4866	8.00	43.8933	2.7299	1.1562	35.0933	1.3333

TABLE VI.—*Labor cost of harvesting and threshing rice by the Batangas yatab method.*

Serial No. of unit.	Area.	Yield.	Laborers.				Time.		Wages in commodity.					Cost per hectare.	Cost per cavan.
			Men.	Women.	Children.	Total.	Average per laborer.	Total.	Total share.	Market price per cavan.	Total value of share.	Average value per laborer.	Average value per laborer per hr.		
	Ha.	*Cavans.*	*No.*	*No.*	*No.*	*No.*	*Hours.*	*Hours.*	*Cavans.*	*Pesos.*	*Pesos.*	*Pesos.*	*Pesos.*	*Pesos.*	*Pesos.*
1	0.3785	8.0	38	92	12	142	0.5228	74.25	2.00	10.00	20.00	0.1408	0.2693	52.8401	2.50
2	0.4383	8.4	30	142	12	184	0.7772	143.00	2.10	10.00	21.00	0.1141	0.1468	47.9123	2.50
3	0.0696	2.4	7	7	1	15	1.5811	23.9166	0.60	10.00	6 00	0.40	0 2529	86.2068	2 50
4	0.1184	3.6		15		15	3.1666	47.50	0.90	10.00	9 00	0.60	0.1894	76.0135	2.50
5	0.132	4.0		4		4	8.	32.00	1.00	10.00	10.00	2.50	0.3125	75.7575	2.50
6	0.1875	7.5	2	2		4	11.5	46.00	1.875	10.00	18.75	4.6875	0.4076	100.00	2.50
7	0.2946	4.4	6	33	13	52	1.7914	93.1666	1.10	10 00	11.00	0.2115	0.1180	37.3387	2.50
8	0.2661	4.0	25	26	10	61	1.2377	75.50	1.00	10.00	10.00	0.1639	0.1324	37.5798	2.50
9	0.2475	3.0	15	26	18	59	0.9307	54.9166	0.75	10.00	7.50	0.1271	0.1365	30.3030	2.50
10	0.5822	14.0	23	45	14	82	2.6752	219.3333	3.00	10 00	35.00	0.4268	0.1595	60.1167	2.50
11	0.1158	2.8	6	11	7	24	1.2222	29.3333	0.70	10.00	7.00	0 2916	0.2386	60.4490	2.50
12	0.2635	5.0	14	24	6	44	1.3484	59.3333	1.25	10 00	12 50	0.2840	0.2106	47.4383	2.50
13	0.3268	8.0	15	44	13	72	1.575	113.40	2.00	10 00	20 00	0 2777	0.1763	61.1995	2.50
Totals	3 4208	75.1	181	471	106	758	36 3283	1011.6497	18.775	130.00	187 75	10 2250	2.7504	773.1552	32.50
Ave.	0 2631	5 7769	13 923	36 2307	8 1538	58 3076	2.7944	77.8192	1.4442	10.00	14 4423	0 7865	0.2115	59.4734	2.50

TABLE VII.—*Comparative summary cost of harvesting rice by various methods arranged according to total-yield groups.*

Total-yield groups.	Laguna *yatab* method. Payment in cash.		Batangas sickle method. Payment in commodity.		*Palót* method. Payment in cash, commodity and subsistence.		*Lincao* method. Payment in cash, commodity and subsistence.		Laguna sickle method. Payment in commodity.		Batangas *yatab* method. Payment in commodity.	
	No. of units in group.	Average harvest cost per cavan.	No. of units in group.	Average harvest cost per cavan.	No. of units in group.	Average harvest cost per cavan.	No. of units in group.	Average harvest cost per cavan.	No. of units in group.	Average harvest cost per cavan.	No. of units in group.	Average harvest cost per cavan.
Cavans.		*Pesos.*		*Pesos.*		*Pesos.*		*Pesos.*		*Pesos.*		*Ppesos.*
1—1.4	3	1.0105									2	2.50
1.5—2.9	4	1.2765									5	2.50
3—4.9	3	1.1121	2	1.875							5	2.50
5—9.9	2	0.7387	9	1.875							1	2.50
10—14			3	1.875								
15—29			6	1.875	3	2.385			9	1.3333		
30—49					4	1.6563	4	1.4552	12	1.3333		
50—74					2	1.40	2	1.563	4	1.3333		
75—149					1	2.472	3	2.03				
150—274							1	1.582				
Gen. ave.		1.0793		1.875		2.0052		1.7319		1.3333		2.50

This division of the returns indicated that the costs of the different systems of harvesting varied when applied to different group yields, as is shown in Table VIII.

TABLE VIII.—*Maximum and minimum cost systems of hand harvesting rice for various total-yield groups.*

Yield groups.	Maximum cost system.	Minimum cost system.
Cavans.		
1 —1.4	Laguna *yatab* [a]	Laguna *yatab* [a]
1.5—2.9	Batangas *yatab*	Laguna *yatab*
3 —4.9	Batangas *yatab*	Laguna *yatab*
5 —9.9	Batangas *yatab*	Laguna *yatab*
10 —14	Batangas *yatab*	Batangas sickle
15 —29	*Palót*	Laguna sickle
30 —49	*Palót*	Laguna sickle
50 —74	*Lincao*	Laguna sickle
75 —149	*Palót*	*Lincao*
150 —274	*Lincao* [a]	*Lincao* [a]

[a] Only one system was surveyed for these yield groups.

The total-yield grouping indicates, within the limits of this experiment that the Laguna *yatab* method was the minimum cost, and the Batangas *yatab* the maximum cost system. This conclusion is supported by the general results for all yields.

If each system be examined as to its application to varying total-yield groups, the results will appear as in Table IX.

TABLE IX.—*Maximum and minimum cost total-yield groups for various systems of hand harvesting rice.*

System.	Total-yield group showing maximun cost.	Total-yield group showing minimum cost.
Laguna *yatab*	1.5—2.9	5—9.9
Batangas sickle	[a]	[a]
Palót	75—149	50—74
Lincao	75—149	30—49
Laguna sickle	[a]	[a]
Batangas *yatab*	[a]	[a]

[a] Share systems having a constant cost per cavan.

Of the varying systems the Laguna *yatab* method was employed at maximum cost for the 1.5-2.9 total-yield group and at minimum cost for the 5-9.9 total-yield group. The Batangas sickle, Laguna sickle,and Batangas *yatab* methods were share systems and consequently had constant yield cost in all the total-yield groups. The *palót* method was employed at maximum cost for the 75-149 total-yield group and at minimum cost for the 50-74 total-yield group. The *lincáo* method was employed at maximum cost for the 75-149 total-yield group and at minimum cost for the 30-49 total-yield group.

SUMMARY OF CONCLUSIONS

(1) Classifying the various methods of hand-harvesting of rice examined in these surveys we have as follows: (a) cash payment systems; (b) part cash, part share payment systems; (c) share payment systems.

(2) The average harvesting cost per cavan by the Laguna *yatab* method (payment in cash) was ₱1.0793; by the Batangas sickle method (payment in share), ₱1.8750; by the *palót* method (payment in cash and share), ₱2.0052; by the *lincao* method (payment as in *palót*), ₱1.7319; by the Laguna sickle method (payment in share), ₱1.3333; and by the Batangas *yatab* method (payment as in Batangas sickle and Laguna sickle), ₱2.50. These surveys have indicated that a cash payment system brought the minimum average harvesting cost.

(3) The general average harvesting cost per cavan, as computed from all methods, was ₱1.7072, which is equivalent to 20.084 per cent of the current market price per cavan of palay.

(4) It is to be hoped that more accurate cost relatives may be arrived at in the future as a result of wider survey. The method of obtaining and computing data followed in this paper may be used as a model

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ILLUSTRATIONS

Plate I

Fig. 1. The *yatab* of the Batangas and Laguna region.
2. The *lilik*, or sickle, of the Batangas and Laguna region.
3. The *lincao* of the Laguna, Bulacan, and Nueva Ecija regions.
4. The *palót* of the Bulacan and Nueva Ecija regions.
5. The *palót* of the Pangasinan region.
6. The *gamlang* of the Pangasinan region.

THE EFFECT ON THE GROWTH OF RICE OF THE ADDITION OF AMMONIUM AND NITRATE SALTS TO SOIL CULTURES[1]

By Sam F. Trelease and Pedro Paulino

THREE TEXT FIGURES

The experiments reported in this paper deal with the growth of rice in cultures containing water-saturated soil to which the three elements, phosphorus, potassium, and nitrogen, were added in various proportions. Each culture was supplied with a three-salt mixture composed of primary calcium phosphate [$Ca(H_2PO_4)_2$], potassium sulphate [K_2SO_4], and a nitrogenous salt. Four different nitrogenous salts were used; namely, ammonium sulphate [$(NH_4)_2SO_4$], ammonium nitrate [NH_4NO_3], calcium nitrate [$Ca(NO_3)_2$], and sodium nitrate [$NaNO_3$]. The primary aim of the experiments was to compare the effects of these four nitrogenous salts on the yields of rice in soil cultures. Four groups of cultures, which were similar to each other except as to the form in which nitrogen was supplied, were employed. In Group A, $(NH_4)_2SO_4$ was used; in Group B, the same number of gram-molecules of nitrogen was used, but in the form of NH_4NO_3, which supplied ammonium and nitrate nitrogen; in Group C, the same molecular amount of nitrogen was used, but in the form of $Ca(NO_3)_2$, which supplied nitrate nitrogen; and in Group D, the same molecular amount of nitrogen was used, but in the form of $NaNO_3$, which supplied nitrate nitrogen, in combination with the non-essential element sodium.

In all of the fertilizer mixtures sulphur and calcium were present in addition to phosphorus, potassium, and nitrogen; thus the three salts used in each group of cultures contained all of the elements essential for plants, except iron and magnesium. The mixtures of Group D, it will be noted, contained the non-essential element sodium.

Various workers have already reported that nitrogen in the nitrate form NO_3^- alone is of but little value to rice plants when grown with continuous irrigation or in solution cultures, while ammonium nitrogen alone or a combination of ammonium and nitrate nitrogen is beneficial (1), (2), (3). It was therefore anticipated that the cultures of Group A, containing ammonium nitrogen, would give better growth than those of Groups C and D, containing only nitrate nitrogen. But it was considered desirable to make a further study of the problem by the tests with many sets of salt proportions. The initial osmotic values of all the salt mixtures were approximately the same, and each component salt was varied in a systematic manner. The experiments were carried out in the Department of Plant Physiology of the College of Agriculture, Los Baños, P. I. They form a continuation of earlier tests made at the College of Agriculture (4).

In each group of cultures (A, B, C, and D) fifteen sets of proportions of three salts were added to the soil. The composition of these cultures may be illustrated by means of those of Group A. In this group, fifteen sets of propor-

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tions of the three salts, $Ca(H_2PO_4)_2$, K_2SO_4, and $(NH_4)_2SO_4$, were used. No two sets of proportions were alike, and the fifteen included all sets of proportions of the three salts with each salt varying, from set to set, by increments of one seventh of the total salt content of the mixture, which was osmotically the same in all sets. The increments by which each salt was varied were based on the calculated osmotic value of the salts in water. The method of varying the salt proportions was similar to that employed in sand, solution, and soil cultures by various workers (4), (5), (6), (7). In the present experiments water-saturated soil was used as the culture medium, and the salts were supplied in addition to those already present in the soil. The quantity of salt added to each culture of Group A was calculated to be sufficient to give in 19 liters of water a total osmotic concentration of approximately 1.0 atmospheres at 25°C. The unit of variation was one seventh of this calculated quantity.

The salt combinations are represented by means of triangular diagrams in Figure 1. Each of the intersections of lines represents a single salt combination. In the triangle for Group A the lowest row of intersections (R1)denotes salt mixtures in which one seventh of the total osmotic concentration is due to $Ca(H_2PO_4)_2$; the second row denotes those having two sevenths due to this salt, etc.; while the apex of the triangle (R5) denotes a single mixture having five sevenths due to $Ca(H_2PO_4)_2$. The line of intersections composing the left-hand margin represents salt mixtures having one seventh of the total concentration due to $(NH_4)_2SO_4$, while the intersection at the extreme right denotes a combination in which five sevenths are due to this salt. The intersections making up the right-hand margin represent salt combinations having one seventh of the total osmotic value due to K_2SO_4, while the intersection at the extreme left represents a mixture having five sevenths due to the potassium salt. The cultures are named by the row number and the number of the culture within the row; for example, R1C4. It is evident that the salt combination for this culture, R1C4, has one seventh of the total osmotic concentration due to $Ca(H_2PO_4)_2$, four sevenths to $(NH_4)_2SO_4$, and two sevenths to K_2SO_4.

The description just given refers to the cultures of Group A, whose salt mixtures contain nitrogen in the form of the $(NH_4)_2SO_4$. To distinguish this group, the culture numbers are preceded by the letter A; for example, AR1C4. The cultures of Group B were similar to those of Group A, except that $NH_4NO_3$was used to supply the nitrogen. In Group C, $Ca(NO_3)_2$ supplied the nitrogen; and in Group D, $NaNO_3$ supplied the nitrogen. The cultures of Groups B, C, and D are shown together with those of Group A, in the diagrams of Figure 1.

Table I gives the culture numbers and number of gram-molecules of each salt needed to produce the required partial salt concentrations. It also shows for each salt mixture the number of gram-molecules of N_2, the relative number of molecular units of nitrogen, and the calculated osmotic value in 19 liters of water. Since the salt mixtures were all calculated to have the same number of gram-molecules of nitrogen, the osmotic values differed somewhat in the four groups of cultures. In Groups A and C all of the salt mixtures had a value of 1.0 atm.; in Group B they ranged from 0.80 to 0.96 atm.; and in Group D they ranged from 1.06 to 1.32 atm.

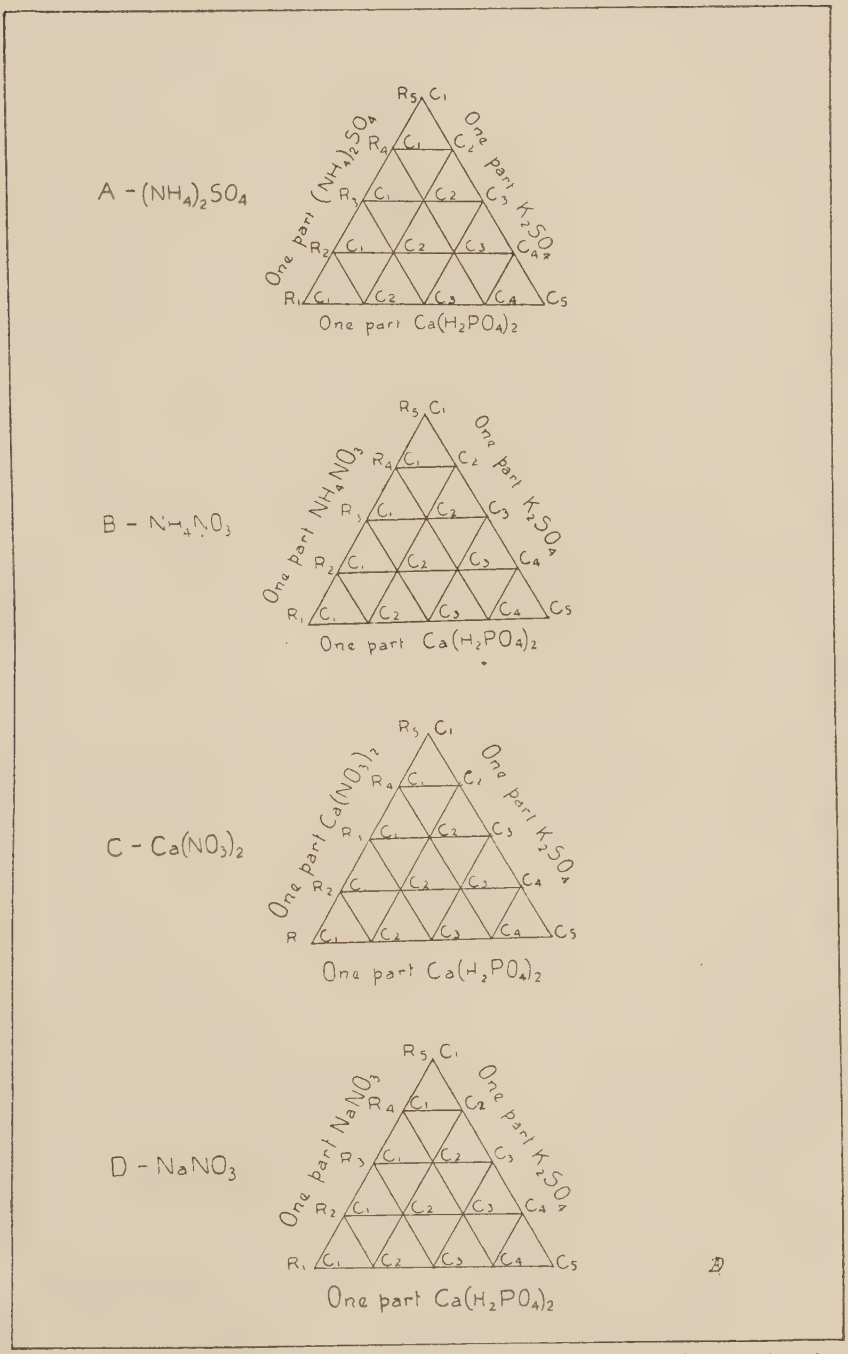

Fig. 1. Triangular diagrams showing culture numbers and salt proportions for each of the four groups of cultures.

TABLE I.—*Culture numbers and composition of each of the salt mixtures. Also the number of gram molecules of N_2, the relative molecular units of nitrogen, and the osmotic value of each salt mixture.*

Culture number.	$Ca(H_2PO_4)_2$.	H_2SO_4.	$(NH_4)_2SO_4$.	NH_4NO_3.	$Ca(NO_3)_2$	$NaNO_3$.	N_2.	Relative molecular units of nitrogen.[a]	Osmotic value.[b]
	gm.-mol.	*gm.-mol.*	*gm.-mol.*	*gm.-mol.*	*gm.-mol.*	*gm.-mol.*	*gm. mol.*		*atm.*
AR1C1	0.0429	0.2143	0.0429	———	———	———	0.0429	1	1.00
AR1C2	0.0429	0.1714	0.0857	———	———	———	0.0857	2	1.00
AR1C3	0.0429	0.1286	0.1286	———	———	———	0.1286	3	1.00
AR1C4	0.0429	0.0857	0.1714	———	———	———	0.1714	4	1.00
AR1C5	0.0429	0.0429	0.2143	———	———	———	0.2143	5	1.00
AR2C1	0.0857	0.1714	0.0429	———	———	———	0.0429	1	1.00
AR2C2	0.0857	0.1286	0.0857	———	———	———	0.0857	2	1.00
AR2C3	0.0857	0.0857	0.1286	———	———	———	0.1286	3	1.00
AR2C4	0.0857	0.0429	0.1714	———	———	———	0.1714	4	1.00
AR3C1	0.1286	0.1286	0.0429	———	———	———	0.0429	1	1.00
AR3C2	0.1286	0.0857	0.0857	———	———	———	0.0857	2	1.00
AR3C3	0.1286	0.0429	0.1286	———	———	———	0.1286	3	1.00
AR4C1	0.1714	0.0857	0.0429	———	———	———	0.0429	1	1.00
AR4C2	0.1714	0.0429	0.0857	———	———	———	0.0857	2	1.00
AR5C1	0.2143	0.0429	0.0429	———	———	———	0.0429	1	1.00
BR1C1	0.0429	0.2143	———	0.0429	———	———	0.0429	1	0.96
BR1C2	0.0429	0.1714	———	0.0857	———	———	0.0857	2	0.92
BR1C3	0.0429	0.1286	———	0.1286	———	———	0.1286	3	0.88
BR1C4	0.0429	0.0857	———	0.1714	———	———	0.1714	4	0.84
BR1C5	0.0429	0.0429	———	0.2143	———	———	0.2143	5	0.80
BR2C1	0.0857	0.1714	———	0.0429	———	———	0.0429	1	0.96
BR2C2	0.0857	0.1286	———	0.0857	———	———	0.0857	2	0.92
BR2C3	0.0857	0.0857	———	0.1286	———	———	0.1286	3	0.88
BR2C4	0.0857	0.0429	———	0.1714	———	———	0.1714	4	0.84
BR3C1	0.1286	0.1286	———	0.0429	———	———	0.0429	1	0.96
BR3C2	0.1286	0.0857	———	0.0857	———	———	0.0857	2	0.92
BR3C3	0.1286	0.0429	———	0.1286	———	———	0.1286	3	0.88
BR4C1	0.1714	0.0857	———	0.0429	———	———	0.0429	1	0.96
BR4C2	0.1714	0.0429	———	0.0857	———	———	0.0857	2	0.92
BR5C1	0.2143	0.0429	———	0.0429	———	———	0.0429	1	0.96
CR1C1	0.0429	0.2143	———	———	0.0429	———	0.0429	1	1.00
CR1C2	0.0429	0.1714	———	———	0.0857	———	0.0857	2	1.00
CR1C3	0.0429	0.1286	———	———	0.1286	———	0.1286	3	1.00
CR1C4	0.0429	0.0857	———	———	0.1714	———	0.1714	4	1.00
CR1C5	0.0429	0.0429	———	———	0.2143	———	0.2143	5	1.00
CR2C1	0.0857	0.1714	———	———	0.0429	———	0.0429	1	1.00
CR2C2	0.0857	0.1286	———	———	0.0857	———	0.0857	2	1.00
CR2C3	0.0857	0.0857	———	———	0.1286	———	0.1286	3	1.00
CR2C4	0.0857	0.0429	———	———	0.1714	———	0.1714	4	1.00
CR3C1	0.1286	0.1286	———	———	0.0429	———	0.0429	1	1.00
CR3C2	0.1286	0.0857	———	———	0.0857	———	0.0857	2	1.00
CR3C3	0.1286	0.0429	———	———	0.1286	———	0.1286	3	1.00
CR4C1	0.1714	0.0857	———	———	0.0429	———	0.0429	1	1.00
CR4C2	0.1714	0.0429	———	———	0.0857	———	0.0857	2	1.00
CR5C1	0.2143	0.0429	———	———	0.0429	———	0.0429	1	1.00
DR1C1	0.0429	0.2143	———	———	———	0.0857	0.0429	1	1.06
DR1C2	0.0429	0.1714	———	———	———	0.1714	0.0857	2	1.13
DR1C3	0.0429	0.1286	———	———	———	0.2571	0.1286	3	1.19
DR1C4	0.0429	0.0857	———	———	———	0.3428	0.1714	4	1.25
DR1C5	0.0429	0.0429	———	———	———	0.4285	0.2143	5	1.32
DR2C1	0.0857	0.1714	———	———	———	0.0857	0.0429	1	1.06
DR2C2	0.0857	0.1286	———	———	———	0.1714	0.0857	2	1.13
DR2C3	0.0857	0.0857	———	———	———	0.2571	0.1286	3	1.19
DR2C4	0.0857	0.0429	———	———	———	0.3428	0.1714	4	1.25
DR3C1	0.1286	0.1286	———	———	———	0.0857	0.0429	1	1.06
DR3C2	0.1286	0.0857	———	———	———	0.1714	0.0857	2	1.13
DR3C3	0.1286	0.0429	———	———	———	0.2571	0.1286	3	1.19
DR4C1	0.1714	0.0857	———	———	———	0.0857	0.0429	1	1.06
DR4C2	0.1714	0.0429	———	———	———	0.1714	0.0857	2	1.13
DR5C1	0.2143	0.0429	———	———	———	0.0857	0.0429	1	1.06

[a] These values also represent the relative osmotic units for the cultures of groups A and C.

[b] Osmotic value which the salt mixture would have in 19 liters of water.

EXPERIMENTS AND RESULTS

Two sets of experiments (Set 1 and Set 2) with similar experimental methods were carried out. Any minor differences between the methods of the two sets will be pointed out as the methods are described.

Seeds of the *sanglay puti* variety of rice were soaked in water for fourteen hours and were planted in seedboxes that contained sieved garden soil having a favorable moisture content. The seeds for Set 1 were planted on June 26 and germinated on June 29, 1919; those for Set 2 were planted on August 4 and germinated on August 7, 1919.

The culture vessels were ordinary tinned petroleum cans, having a capacity of about 19 liters. They were thoroughly cleaned before use. The inside of each can was paraffined, by heating the can and then running melted paraffin over the inner surfaces.

The soil used in these experiments was a clay loam taken from a place on the College Farm that had previously been planted with sweet potatoes. The soil was pulverized and thoroughly mixed. In Set 1, 20 kilograms of soil were added to each culture vessel; in Set 2, 21 kilograms of soil were added.

Stock solutions for the two sets of experiments were prepared from boiled water and the salts: K_2SO_4, $(NH_4)_2SO_4$, $Ca(NO_3)_2$, NH_4NO_3, and $NaNO_3$. The necessary amount of each fertilizer salt, shown in Table I, was thoroughly mixed with the soil. The $Ca(H_2PO_4)_2$ was added as a powder, and the other salts in the form of solutions.

The cultures were put in rows, one meter apart each way, in a place where they were all subjected to about the same climatic conditions. To each can sufficient water was added to saturate the soil. Eight healthy and apparently similar seedlings, the tops of which had been trimmed, were transplanted to each culture. Transplanting for Set 1 occurred on August 13, 1919; for Set 2, on September 13, 1919. Except when there was rainfall, the cultures were watered every day, in order to keep a nearly constant water level, about 3 centimeters above the surface of the soil. On September 8, the cultures of Set 1 were thinned, leaving four vigorous plants in each culture; and on September 20 the cultures were thinned again, leaving two vigorous plants in each culture. The same operation upon the cultures of Set 2 occurred on October 9 and 16, respectively.

In Set 1 measurements were not made of the leaves, but in Set 2 the leaves were measured just before the plants flowered. The length was measured from the apex to the junction of the blade and the leaf sheath, and the width was measured where it seemed to be greatest. Thirty leaves were measured in each culture.

The cultures of Set 1 were harvested on November 8, and those of Set 2, on December 22, 1919. The panicles were cut from the top node of the culm and put in paper bags, and the straw was harvested separately. Immediately after harvest the length of each panicle was measured from the last node of the culm to the tip of the panicle. The number of bearing culms was recorded, and each bearing culm was measured from the base to the last node. The grain was removed from the panicles and allowed to become air-dry before it was weighed. The straw was also allowed to become air-dry before being weighed.

TABLE II.—*Yield data for rice plants harvested on November 8, 1919. For two plants. Set 1.*

Culture number.	Air-dry wt. of straw.	Air-dry wt. of grain.	Number of bearing culms.	Av. length of culms.	Av. length of panicles.
	gm.	*gm.*		*cm.*	*cm.*
AR1C1	67	77	29	83.6	22
AR1C2	137	149	54	91.4	22.2
AR1C3	135	169	53	93.6	22.5
AR1C4	177	197	56	95.3	23.0
AR1C5	173	174	65	93.5	23.6
AR2C1	82	94	35	89.4	24.3
AR2C2	84	97	28	92.6	22.5
AR2C3	144	145	46	96.2	21.6
AR2C4	146	166	50	97.4	23.3
AR3C1	53	53	26	92.6	22.1
AR3C2	80	89	30	91.7	22.0
AR3C3	110	131	42	98.4	24.9
AR4C1	56	59	24	89.7	20.4
AR4C2	104	111	38	92.6	22.4
AR5C1	58	57	21	88.4	21.6
BR1C1	43	46	16	88.0	25.4
BR1C2	55	59	22	90.2	21.7
BR1C3	60	65	21	97.1	22.5
BR1C4	111	115	35	98.6	22.7
BR1C5	77	92	28	93.1	23.1
BR2C1	53	46	17	90.9	22.6
BR2C2	49	48	16	95.0	23.6
BR2C3	66	74	23	98.2	23.4
BR2C4	87	92	35	94.5	21.3
BR3C1	42	40	17	89.7	21.8
BR3C2	55	56	16	95.5	22 3
BR3C3	72	78	23	98.5	23.6
BR4C1	40	41	17	86.5	22.0
BR4C2	66	68	22	89.7	21.5
BR5C1	43	49	15	86.8	23.6
CR1C1	33	36	11	92.6	25.2
CR1C2	42	34	16	83.5	21.3
CR1C3	35	38	15	80.1	20.2
CR1C4	46	45	20	86.5	21.1
CR1C5	50	48	19	90.3	20.6
CR2C1	35	22	11	85.3	22.0
CR2C2	39	34	15	84.5	21.0
CR2C3	36	32	12	86.2	22.4
CR2C4	50	42	20	87.6	20.8
CR3C1	28	23	12	81.4	20.9
CR3C2	31	32	13	82.8	22.8
CR3C3	37	37	16	80.1	20.8
CR4C1	36	31	16	84.7	20.4
CR4C2	38	35	15	80.4	21.0
CR5C1	38	34	12	85.9	22.7
DR1C1	35	36	16	82.8	20.3
DR1C2	39	39	12	94.1	23.1
DR1C3	43	38	12	91.3	22.6
DR1C4	44	40	16	89.7	21.1
DR1C5	48	48	15	89.0	22.3
DR2C1	38	28	13	85.6	21.2
DR2C2	47	41	14	92.7	22.2
DR2C3	39	42	17	80.3	22.0
DR2C4	47	53	17	91.5	22.7
DR3C1	39	38	15	86.4	22.0
DR3C2	38	42	18	82.0	20.4
DR3C3	36	31	11	89.0	23.5
DR4C1	36	34	13	86.1	21.3
DR4C2	37	33	17	81.4	20.7
DR5C1	36	37	18	79.0	20.8
Control 1	23	26	9	85.3	21.6
Control 2	26	26	12	79.4	21.8
Control 3	25	18	11	77.2	21.5
Control 4	25	28	13	80.0	20.8
Av. Control	25	25	11	80.5	21.4

TABLE III.—*Yield data for rice plants harvested on December 22, 1919. For two plants. Set 2.*

Culture number.	Air-dry wt. of straw.	Air-dry wt. of grain.	Number of bearing culms.	Av. length of culms.	Av. length of panicles.	Av. length of leaves.	Av. width of leaves.
	gm.	*gm.*		*cm.*	*cm.*	*cm.*	*cm.*
AR1C1	42	45	21	82.6	19.2	45.5	1.33
AR1C2	74	85	32	89.8	22.0	50.3	1.36
AR1C3	102	139	46	93.9	22.1	48.7	1.40
AR1C4	130	190	58	91.3	19.8	49.9	1.44
AR1C5	141	162	55	93.7	23.8	48.3	1.38
AR2C1	47	53	19	88.6	20.7	47.3	1.36
AR2C2[a]	96	66	41	93.6	22.4	47.5	1.46
AR2C3	122	122	44	94.8	24.2	46.6	1.52
AR2C4	148	167	53	94.1	23.5	44.6	1.47
AR3C1	59	67	27	90.3	20.5	44.0	1.38
AR3C2	116	107	44	95.8	21.6	42.6	1.76
AR3C3	143	146	48	92.1	23.3	45.4	1.44
AR4C1	98	83	34	91.1	22.0	43.9	1.35
AR4C2	122	106	40	90.2	22.7	44.7	1.27
AR5C1	76	61	27	86.3	20.7	45.0	1.29
BR1C1	30	37	16	83.0	20.3	39.7	1.33
BR1C2	63	64	26	88.0	20.6	45.3	1.33
BR1C3	88	87	30	95.9	22.4	49.0	1.44
BR1C4	126	134	45	98.3	23.1	47.5	1.45
BR1C5	134	143	41	99.2	26.1	53.0	1.59
BR2C1	35	33	16	84.4	18.8	38.1	1.11
BR2C2	66	62	21	96.4	21.9	41.9	1.21
BR2C3	110	112	37	97.4	22.2	48.5	1.37
BR2C4	135	141	49	100.5	23.0	47.4	1.45
BR3C1	41	42	19	84.3	20.3	38.4	1.08
BR3C2	58	63	26	87.1	20.6	38.9	1.21
BR3C3	100	110	40	96.2	21.1	46.9	1.33
BR4C1	40	28	12	85.7	20.3	37.8	1.07
BR4C2	76	66	25	89.7	20.6	42.6	1.31
BR5C1	51	40	16	84.7	19.7	41.8	1.18
CR1C1	19	22	11	76.8	19.7	37.1	0.98
CR1C2	35	31	17	85.5	21.4	46.0	1.36
CR1C3	52	49	20	89.6	21.3	47.1	1.22
CR1C4	51	62	24	90.9	22.1	42.2	1.32
CR1C5	69	87	28	101.0	24.2	45.2	1.36
CR2C1	26	20	13	85.1	18.5	35.1	0.94
CR2C2	45	43	17	89.9	20.9	40.8	1.24
CR2C3	88	91	31	97.2	23.2	41.2	1.29
CR2C4	85	88	30	96.6	22.8	49.0	1.41
CR3C1	28	30	15	79.0	19.1	35.8	1.00
CR3C2	61	57	23	88.8	20.5	42.6	1.18
CR3C3	75	84	31	87.5	22.2	43.4	1.19
CR4C1	30	27	13	82.9	19.2	34.1	0.91
CR4C2	46	51	23	81.8	20.1	35.5	1.04
CR5C1	23	21	13	71.2	18.5	35.7	0.98
DR1C1	27	22	11	84.3	17.5	39.0	1.04
DR1C2	41	42	16	92.5	21.8	42.4	1.37
DR1C3	47	47	21	86.0	21.8	41.9	1.24
DR1C4	63	60	23	88.3	23.1	46.7	1.36
DR1C5	91	89	32	98.1	23.0	44.3	1.31
DR2C1	28	22	13	81.0	20.4	34.4	1.00
DR2C2	48	45	21	86.6	19.5	38.4	1.06
DR2C3	84	77	30	94.5	22.5	41.6	1.22
DR2C4	96	113	37	93.4	22.7	50.6	1.31
DR3C1	29	24	11	79.8	20.4	37.7	0.94
DR3C2	45	45	20	84.8	20.2	40.8	1.23
DR3C3	70	79	25	88.9	22.5	42.9	1.25
DR4C1	35	24	11	83.4	19.0	35.1	1.11
DR4C2	56	51	21	82.9	20.8	40.7	1.28
DR5C1	33	25	11	81.3	20.2	36.6	1.12
Control 1	12	13	6	69.9	19.6	36.6	1.08
Control 2	11	13	6	81.2	21.2	32.0	0.94
Control 3	11	11	6	72.0	20.1	39.2	1.04
Control 4	12	12	7	73.6	19.0	36.4	0.97
Av. Control	12	12	6	74.2	20.0	36.9	1.01

[a] Attacked by rats.

Yield data.—Table II, which gives the actual yield data of rice plants of Set 1, presents the air-dry weights of straw and of grain, the number of bearing culms, the average length of culms, and the average length of panicles. Table III is similar to Table II, but gives the actual yield data for the plants of Set 2. In Table III two additional measurements are given: the average length of leaves and the average width of leaves.

Relative yields.—Table IV shows the relative dry yields of straw, on the basis of the culture giving highest yield in each group considered as 100. The first column gives the culture number. The table is divided into four sections, referring to the $(NH_4)_2SO_4$, NH_4NO_3, $Ca(NO_3)_2$, and $NaNO_3$ groups, respectively. For each group are given the relative yields for Set 1, the relative yields for Set 2, the averages of the relative values, and (in black-face type) the relative yields on the basis of the highest average considered as 100. The relative yields (on the basis of the highest average as 100) have been plotted on the triangular diagrams of Figure 2. The arrangement of Table V, which shows the relative dry yields of grain, is the same as that of Table IV. The relative yields (on the basis of the highest average as 100) have been plotted on the triangular diagrams of Figure 3.

DISCUSSION OF RESULTS

RELATION OF SALT PROPORTIONS TO YIELDS

Straw yields.—The triangular diagrams of Figure 2 show the distribution of the relative straw yields with respect to the sets of salt proportions. High yields are denoted in the diagrams by dots, low yields by circles, and medium yields are without special designation. These diagrams indicate which salts were most influential in promoting the growth of the rice plants.

It will be seen from the diagrams that high yields of straw in the $(NH_4)_2SO_4$ and NH_4NO_3 groups are indicated for cultures R1C4, R1C5, and R2C4; and in the $Ca(NO_3)_2$ and $NaNO_3$ groups, for cultures R1C5, R2C3, and R2C4. Thus high yields were obtained with salt mixtures in which only one or two sevenths of the total osmotic value was due to $Ca(H_2PO_4)_2$. Low yields, also, are in general indicated for salt mixtures with low proportions of $Ca(H_2PO_4)_2$. Since both high and low yields accompany low proportions of $Ca(H_2PO_4)_2$, no definite correlation appears to exist between the production of straw and the proportion of $Ca(H_2PO_4)_2$.

The diagrams show that, in general, high yields accompany low proportions of K_2SO_4, and that low yields accompany high proportions of this salt, thus indicating an inverse relationship between the amount of K_2SO_4 and the production of straw. But since low yields were obtained in the $Ca(NO_3)_2$ and $NaNO_3$ groups with culture R5C1, one of the cultures characterized by the lowest proportion of K_2SO_4, the suggested inverse relationship is not very definite. About all that can be stated here is that increased proportions of K_2SO_4 did not result in increased yields of straw.

The diagrams suggest, however, a direct correlation between the proportions of the nitrogenous salts and the yields of straw. In the case of the $(NH_4)_2SO_4$ group, high yields are indicated for the three cultures having the highest proportions of $(NH_4)_2SO_4$, and low yields for cultures having the lowest proportions of this salt. It appears, therefore, that high yields of straw are definitely correlated

with high proportions of $(NH_4)_2SO_4$ in the salt mixtures containing $Ca(H_2PO_4)_2$, K_2SO_4, and $(NH_4)_2SO_4$ and that low yields of straw are confined to cultures having lowest proportions of $(NH_4)_2SO_4$. The present tests thus agree with earlier tests at the College (1). The diagram for the NH_4NO_3 group yields a conclusion similar to that just stated for the $(NH_4)_2SO_4$ group; namely, that high straw yields are definitely correlated with high proportions of the nitrogenous salt, NH_4NO_3, and low yields with low proportions of this salt. The diagrams for the $Ca(NO_3)_2$ and $NaNO_3$ groups also indicate a correlation between the proportion of the nitrogenous salt and the relative yields of straw; high yields accompany high proportions of $Ca(NO_3)_2$ and $NaNO_3$, and low yields accompany low proportions of these salts.

It may therefore be concluded from these diagrams that, in general, little or no correlation existed, under these experimental conditions, between the yields of straw and the proportion of either $Ca(H_2PO_4)_2$ or K_2SO_4, but that a direct correlation existed between the proportion of the nitrogenous salts and the yields of straw, increased yields of straw accompanying increased proportions of the nitrogenous salts. This was true with the $(NH_4)_2SO_4$ group, in which nitrogen was supplied in the ammonium form alone; with the NH_4NO_3 group, in which nitrogen was supplied in both the ammonium and the nitrate forms; with the $Ca(NO_3)_2$ group, in which nitrogen was supplied in the nitrate form alone; and with $NaNO_3$ group, in which nitrogen was supplied in the nitrate form alone. Relative yields of straw were roughly proportional to the amount of nitrogen, when this was supplied in the ammonium form alone, in the nitrate form alone or in a combination of both forms.

The relative straw yields of the control cultures, which received no fertilizer, are given at the bottom of Table IV. The indicated average relative yield of the control culture is 11 per cent of the yield of the best culture containing $(NH_4)_2SO_4$, 16 per cent of the yield of the best culture containing NH_4NO_3, 32 per cent of the yield of the best culture containing $Ca(NO_3)_2$, and 33 per cent of the best culture containing $NaNO_3$. Thus with $(NH_4)_2SO_4$ a yield was obtained which was about 9.1 times the yield obtained without fertilizer; with NH_4NO_3, about 6.3 times the yield without fertilizer; with $Ca(NO_3)_2$, about 3.1 times the yield without fertilizer; and with $NaNO_3$, about 3.0 times the yield without fertilizer.

Grain yields.—Conclusions that are similar to those just stated regarding straw yields, are suggested by Fig. 3, showing relative yields of grain. Grain yields are apparently not related to the proportions of either $Ca(H_2PO_4)_2$ or K_2SO_4, but are definitely correlated with the proportion of nitrogenous salt. High yields of grain are, in general, confined to salt mixtures having high proportions of the nitrogenous salt, and low yields are confined to combinations having the smallest amount of the nitrogenous salts. This relation between the yields of grain and the nitrogen content of the fertilizer mixture held true with all four nitrogenous salts. Ammonium alone, a combination of ammonium and nitrate, or nitrate alone, appeared to be effective in increasing the grain yields of the rice plants.

TABLE IV.—*Relative dry yields of straw; culture giving highest yield considered as 100.*

Culture number.	Group A [$(NH_4)_2SO_4$].				Group B [NH_4NO_3].				Group C [$Ca(NO_3)_2$].				Group D [$NaNO_3$].			
	Relative, Set 1.	Relative, Set 2.	Average of relative yields for 2 sets.	Average on basis of highest as 100.	Relative, Set 1.	Relative, Set 2.	Average of relative yields for 2 Sets.	Average on basis of highest as 100.	Relative, Set 1.	Relative, Set 2.	Average of relative yields for 2 Sets.	Average, on basis of highest as 100.	Relative, Set 1.	Relative, Set 2.	Average of relative yields for 2 Sets.	Average on basis of highest as 100.
R1C1	38	28	33	**34**	39	22	31	**32**	66	22	44	**44**	73	28	51	**52**
C2	72	50	61	**62**	50	48	49	**51**	84	40	62	**63**	81	43	62	**63**
C3	76	69	73	**75**	54	65	60	**62**	70	59	65	**66**	90	49	70	**71**
C4	100 (177)	88	94	**97**	100 (111)	93	97	**100**	92	58	75	**76**	92	66	79	**80**
C5	98	95	97	**100**	69	99	84	**85**	100 (50)	78	89	**90**	100 (48)	95	98	**99**
R2C1	46	32	39	**40**	50	26	38	**39**	70	30	50	**51**	79	29	54	**55**
C2	47	65	56	**58**	44	49	47	**48**	78	51	65	**66**	98	50	74	**75**
C3	81	82	82	**85**	59	81	70	**72**	72	100 (88)	86	**87**	81	88	85	**86**
C4	82	100 (148)	91	**94**	78	100 (135)	89	**90**	100	97	99	**100**	98	100 (96)	99	**100**
R3C1	30	40	35	**36**	38	30	34	**35**	56	32	44	**44**	81	30	56	**57**
C2	45	78	62	**64**	50	43	47	**48**	62	69	66	**67**	79	47	63	**64**
C3	62	97	80	**82**	65	74	70	**72**	74	85	80	**81**	75	73	74	**75**
R4C1	32	66	49	**51**	36	30	33	**34**	72	34	53	**54**	75	36	56	**57**
C2	59	82	71	**73**	59	56	58	**60**	76	52	64	**65**	77	58	68	**69**
R5C1	33	51	42	**43**	39	38	39	**40**	76	26	51	**52**	75	34	55	**56**
Control	14	8	11	**11**	23	9	16	**16**	50	14	32	**32**	52	13	33	**33**

TABLE V.—*Relative dry yields of grain; culture giving highest yield considered as 100.*

Culture number.	Group A [$(NH_4)_2SO_4$].				Group B [NH_4NO_3].				Group C [$Ca(NO_3)_2$].				Group D [$NaNO_3$].			
	Relative, Set 1.	Relative, Set 2.	Average of relative yields for 2 sets.	Average on basis of highest as 100.	Relative, Set 1.	Relative, Set 2.	Average of relative yields for 2 sets.	Average on basis of highest as 100.	Relative, Set 1.	Relative, Set 2.	Average of relative yields for 2 sets.	Average on basis of highest as 100.	Relative, Set 1.	Relative, Set 2.	Average of relative yields for 2 sets.	Average on basis of highest as 100.
R1C1	39	24	32	**32**	40	26	33	**34**	75	24	50	**51**	68	19	44	**44**
C2	76	45	61	**61**	52	45	49	**51**	71	34	53	**54**	73	37	55	**55**
C3	86	73	80	**80**	67	61	64	**66**	79	54	67	**68**	72	42	57	**57**
C4	100 (197)	100 (190)	100	**100**	100 (115)	94	97	**100**	94	68	81	**83**	75	53	64	**64**
C5	88	85	87	**87**	80	100 (143)	90	**92**	100 (48)	96	98	**100**	91	79	85	**85**
R2C1	48	28	38	**38**	40	22	31	**32**	46	22	34	**35**	53	19	36	**36**
C2	49	35	42	**42**	42	43	43	**44**	71	47	59	**60**	77	40	59	**59**
C3	74	64	69	**69**	64	78	71	**73**	67	100	84	**86**	79	68	74	**74**
C4	84	88	86	**86**	80	99	90	**92**	88	(91) 97	93	**95**	100 (53)	100 (113)	100	**100**
R3C1	27	35	31	**31**	35	29	32	**33**	48	33	41	**42**	72	21	47	**47**
C2	45	56	51	**51**	49	44	47	**48**	67	63	65	**66**	79	40	60	**60**
C3	66	77	72	**72**	68	77	73	**75**	77	92	85	**87**	58	70	64	**64**
R4C1	30	44	37	**37**	36	20	28	**29**	65	30	48	**49**	64	21	43	**43**
C2	56	56	56	**56**	59	46	53	**55**	73	56	65	**66**	62	45	54	**54**
R5C1	29	32	31	**31**	43	28	36	**37**	71	23	47	**48**	70	22	46	**46**
Control	13	6	10	**10**	22	8	15	**15**	52	13	33	**34**	47	11	29	**29**

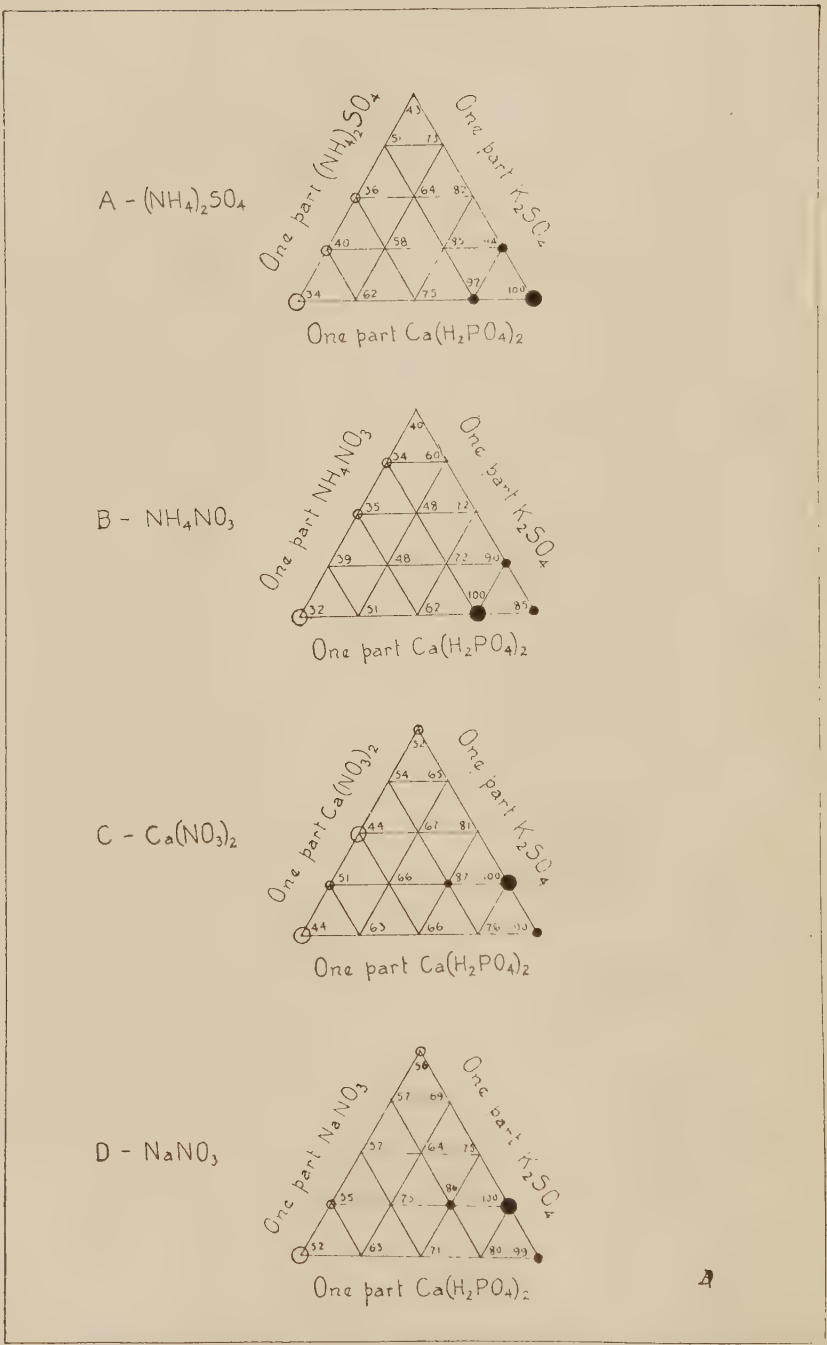

Fig. 2. Diagrams showing relative yields of rice straw. High yields indicated by dots; low, by circles. (Data from Table IV.)

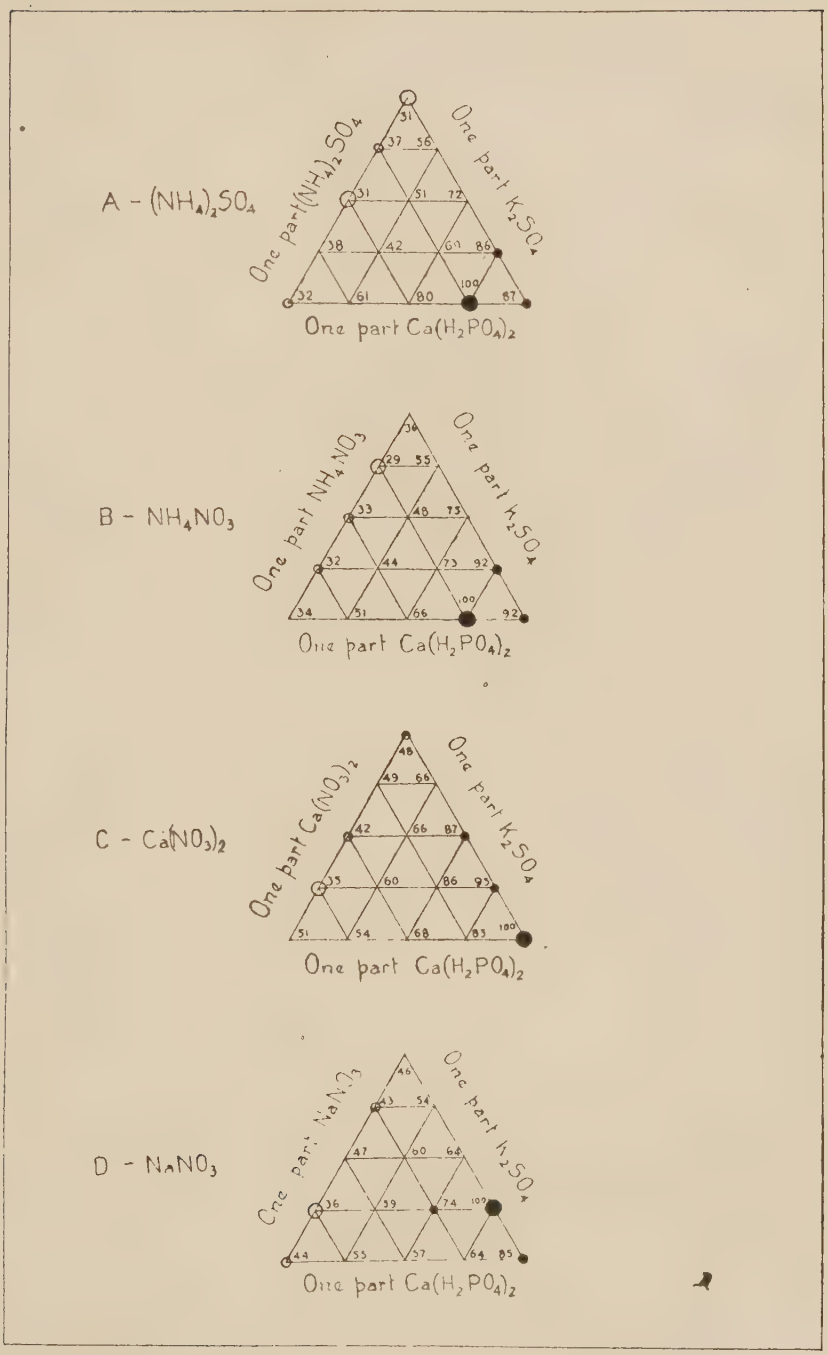

Fig. 3. Diagrams showing relative yields of rice grain. High yields indicated by dots; low, by circles. (Data from Table V.)

The relative grain yields of the control cultures are given at the bottom of Table V. The indicated average relative yield of the control culture is 10 per cent of the yield of the best culture containing $(NH_4)_2SO_4$, 15 per cent of the yield of the best culture containing NH_4NO_3, 34 per cent of the best culture containing $Ca(NO_3)_2$, and 29 per cent of the yield of the best culture containing $NaNO_3$. Thus the yield obtained with $(NH_4)_2SO_4$ was about 10.0 times the yield without fertilizer; with NH_4NO_3 about 6.7 times the yield without fertilizer; with $Ca(NO_3)_2$, about 2.9 times the yield without fertilizer; and with $NaNO_3$, about 3.4 times the yield without fertilizer.

COMPARISON OF YIELDS OBTAINED WITH DIFFERENT FORMS OF NITROGEN

Straw yields.—The data of Tables II and III have been brought together in Table VI in such a way as to show, for each set of salt proportions, the relative effectiveness of the four nitrogenous salts in promoting the production of straw. The first column gives the culture number (R1C1, R1C2, etc.) for each of the cultures; and in the following columns the yields are given as relative numbers, on the basis of those in the $(NH_4)_2SO_4$ group considered as having a relative value of 100. Each of the four sections of the table refers to one of the groups of cultures. In each section are given the relative yields for Set 1, the relative yields for Set 2, and the average of these two relative values. This Table indicates, for each set of salt proportions, which of the four nitrogenous salts should be used in order to obtain the highest yield of straw under the conditions of these experiments. With the salt proportions of culture R1C1, for example, the relative yield with $(NH_4)_2SO_4$ was 100; with NH_4NO_3, 68; with $Ca(NO_3)_2$, 47; and with $NaNO_3$, 58. Thus with the salt proportions of culture R1C1, highest yields were obtained with $(NH_4)_2SO_4$; considerably lower yields were obtained with NH_4NO_3; and still lower yields were obtained with $Ca(NO_3)_2$ or $NaNO_3$. It is apparent that with the salt proportions of R1C1, $(NH_4)_2SO_4$ is much more effective in the production of straw than are any of the other nitrogenous salts.

Inspection of all of the data of Table VI shows that with every set of salt proportions tested, highest relative yields were obtained with $(NH_4)_2SO_4$, which supplied nitrogen in the ammonium form; that lower yields were obtained with NH_4NO_3, which supplied nitrogen in the combination of ammonium and nitrate; and that still lower yields were obtained with $Ca(NO_3)_2$ and $NaNO_3$, which supplied nitrogen in the form of nitrate alone. The yields obtained with $(NH_4)NO_3$ (seventh column) ranged from 56 to 80 per cent of those obtained with the corresponding sets of salt proportions with $(NH_4)_2SO_4$, while the average yield for all sets of salt proportions was 68 per cent of the average with $(NH_4)_2SO_4$. The yields with $Ca(NO_3)_2$ (tenth column) ranged from 33 to 51 per cent of the yields with the corresponding sets of salt proportions with $(NH_4)_2SO_4$, while the average value was 44 per cent. And the yields obtained with $NaNO_3$ (thirteenth column) ranged from 37 to 62 per cent of those obtained with $(NH_4)_2SO_4$, while the average value was 48 per cent. The variations in the relative values for NH_4NO_3, for $Ca(NO_3)_2$, and for $NaNO_3$, indicate that the relative plant-producing power of the nitrogenous salts depends not only upon the type of the nitrogenous salt, but also upon the relative proportions of the potassium and phosphate salts. The general relation between straw yield and the form of nitrogen may be seen from the averages given at the bottom of Table VI. The average

for $(NH_4)_2SO_4$ is 100; for NH_4NO_3, 68; for $Ca(NO_3)_2$, 44; and for $NaNO_3$, 48. Considering all the salt proportions tested, it appears that ammonium and nitrate combined gave a straw yield about two-thirds as high as that obtained with ammonium alone and that nitrate alone gave a yield about one-half as high as that obtained with ammonium alone.

Grain yields.—Table VII is similar in arrangement to Table VI, but refers to grain yields, and gives the relative yields of grain obtained with NH_4NO_3, $Ca(NO_3)_2$, and $NaNO_3$, when the relative yield with $(NH_4)_2SO_4$ is considered as having a value of 100.

This table shows the relative efficiency of the four nitrogen salts in producing grain yields. For example, with the salt proportions of culture R1C1, the relative yield with $(NH_4)_2SO_4$ was 100; with NH_4NO_3, 71; with $Ca(NO_3)_2$, 48; and with $NaNO_3$, 48. It will be seen that the yields obtained with NH_4NO_3 (seventh column) ranged from 51 to 76 per cent of those obtained with corresponding sets of salt proportions with $(NH_4)_2SO_4$, while the average yield for all sets of salt proportions with NH_4NO_3 was 65 per cent of the average with $(NH_4)_2SO_4$. The yields with $Ca(NO_3)_2$ (tenth column) ranged from 28 to 50 per cent of the yields obtained with the corresponding sets of salt proportions with $(NH_4)_2SO_4$, while the average value was 40 per cent. The yields obtained with $NaNO_3$ (thirteenth column) ranged from 26 to 55 per cent of those obtained with $(NH_4)_2SO_4$, while the average value was 42 per cent. The variations in the values for NH_4NO_3, for $Ca(NO_3)_2$, and for $NaNO_3$, suggest, as in the case of straw yields, that the relative plant-producing power of each nitrogenous salt depends, to a certain extent at least, upon the relative proportions of potassium sulphate and primary calcium phosphate in the mixture. Considering all sets of salt proportions, NH_4NO_3 produced 65 per cent of yields obtained with $(NH_4)_2SO_4$; $Ca(NO_3)_2$, 40 per cent; and $NaNO_3$, 42 per cent. With every set of salt proportions tested, higher yields were obtained with $(NH_4)_2SO_4$ than with NH_4NO_3, and higher yields were obtained with NH_4NO_3 than with either $Ca(NO_3)_2$ or $NaNO_3$. The relative effectiveness of $Ca(NO_3)_2$ and $NaNO_3$ varied with the different sets of salt proportions; with some sets $Ca(NO_3)_2$ gave greater yields, while with other sets $NaNO_3$ gave greater yields.

RELATIVE YIELDS PER UNIT OF MOLECULAR NITROGEN ADDED TO THE SOIL

The data of Tables II and III have been treated in Table VIII in such a way as to show, for Set 1, the relative yields of straw per unit of molecular nitrogen added to the soil. The culture numbers are given in the first column. In the second column are shown the relative units of nitrogen, U_n. These units are proportional to the number of gram-molecules of nitrogen (N_2) in the fertilizer mixtures, and range from 1 to 5; the actual number of gram-molecules of nitrogen may be obtained by multiplying the values of U_n by 0.0429. The rest of the table is divided into four sections, which refer to the $(NH_4)_2SO_4$, NH_4NO_3, $Ca(NO_3)_2$, and $NaNO_3$ groups respectively. In each of the sections are given the relative straw yields and the ratio obtained by dividing these yields by the value of U_n. These ratio values indicate the relative yields of straw per unit of molecular nitrogen in the fertilizer mixture. For example, with the salt proportions of culture R1C1, the yield of straw per unit of molecular nitrogen was 67 for the $(NH_4)_2SO_4$ group, 43 for the NH_4NO_3 group, 33 for the $Ca(NO_3)_2$ group, and 35 for the $NaNO_3$

group. With the salt proportions of culture R1C1, therefore, the yield of straw per unit of molecular nitrogen was much higher when this nitrogen was supplied in the form of ammonium alone, as $(NH_4)_2SO_4$, than when supplied in the form of ammonium combined with nitrate, as NH_4NO_3, or in the form of nitrate alone, as $Ca(NO_3)_2$ or $NaNO_3$. In the table may be found the relative yields of straw per unit of nitrogen for all of the other sets of salt proportions. It will be observed that with every set of salt proportions the value of the ratio is higher for the cultures supplied with $(NH_4)_2SO_4$ than it is for the corresponding cultures in which the nitrogen was supplied in the form of ammonium combined with nitrate. The value of this ratio is also higher for all of the cultures having both the ammonium and nitrate nitrogen than it is for the corresponding cultures having the nitrogen as nitrate alone. The value of the ratio is nearly the same for all of the cultures having nitrate nitrogen in the form of $Ca(NO_3)_2$ as it is for the corresponding cultures having nitrate nitrogen in the form of $NaNO_3$.

At the bottom of Table VIII are given the maximum, minimum, and average values for each of the kinds of data. The yields of straw per unit of molecular nitrogen have an average value of 51 for the cultures of the $(NH_4)_2SO_4$ group, of 31 for the cultures of the NH_4NO_3 group, of 21 for the cultures of the $Ca(NO_3)_2$, and of 23 for the cultures of the $NaNO_3$ groups. Thus considering all the sets of salt proportions, the yield obtained with nitrogen in the nitrate form was only about one-half that obtained with nitrogen in the ammonium form; and the yield obtained with nitrogen in the combined form of ammonium and nitrate was about two-thirds as great as that obtained with ammonium alone. This table clearly suggests the superiority of ammonium nitrogen to nitrate nitrogen. It also suggests another point: that although successive increments of nitrogen result in increments in yield, the increments in yield, are not proportional to the increments in nitrogen. Table IX is similar to Table VIII, but refers to Set 2. It suggests conclusions that are similar to those just stated for Set 1. Tables X and XI are similar to Tables VIII and IX, but give data for grain yields. The general conclusions suggested regarding grain yields are similar to those regarding straw yields.

SUMMARY OF CONCLUSIONS

Under the conditions of the experiments here reported, neither grain nor straw yields were correlated in a definite way with the proportions of either primary calcium phosphate or potassium sulphate. Increased yields did not accompany higher proportions of these salts.

Yields of straw and of grain were, however, directly related to the proportions of nitrogenous salts in the fertilizer mixtures; high yields were correlated with high proportions, and low yields with low proportions of nitrogenous salts. This was true with ammonium sulphate, supplying nitrogen in the ammonium form alone; with ammonium nitrate, supplying nitrogen in both the ammonium and the nitrate form; with calcium nitrate supplying nitrogen in the nitrate form alone; and with sodium nitrate, also supplying nitrogen in the nitrate form alone.

TABLE VI.– *Relative dry yield of straw; cultures of group A* $[(NH_4)_2 SO_4]$ *considered as 100.*

Culture number.	Group A $[(NH_4)_2SO_4]$.			Group B $[NH_4NO_3]$.			Group C $[Ca(NO_3)_2]$.			Group D $[NaNO_3]$.		
	Relative, Set 1.	Relative, Set 2.	Relative average for 2 Sets.	Relative, Set 1.	Relative, Set 2.	Relative, average for 2 Sets.	Relative, Set 1.	Relative, Set 2.	Relative average for 2 Sets.	Relative, Set 1.	Relative, Set 2.	Relative average for 2 Sets.
R1C1	100 (67)	100 (42)	100	64	71	68	49	45	47	52	64	58
C2	100 (137)	100 (74)	100	40	85	63	31	47	39	28	55	42
C3	100 (135)	100 (102)	100	44	86	65	26	51	39	32	46	39
C4	100 (177)	100 (130)	100	63	97	80	26	39	33	25	49	37
C5	100 (113)	100 (141)	100	45	95	70	29	49	39	28	65	47
R2C1	100 (82)	100 (47)	100	65	74	70	43	55	49	46	60	53
C2	100 (84)	100 (96)	100	58	69	64	46	47	47	56	50	53
C3	100 (144)	100 (122)	100	46	90	68	25	72	49	27	69	48
C4	100 (146)	100 (148)	100	59	91	75	34	57	46	32	65	49
R3C1	100 (53)	100 (59)	100	79	69	74	55	47	51	74	49	62
C2	100 (80)	100 (116)	100	69	50	60	39	53	46	48	39	44
C3	100 (110)	100 (143)	100	65	70	68	34	52	43	33	49	41
R4C1	100 (56)	100 (98)	100	71	41	56	64	31	48	64	36	50
C2	100 (104)	100 (122)	100	63	62	63	37	38	38	36	46	41
R5C1	100 (58)	100 (76)	100	74	67	71	66	30	48	62	43	53
Av.	100	100	100	—	—	68	—	—	44	—	—	48

TABLE VII.—*Relative dry yields of grain; cultures of group A* $[(NH_4)_2\ SO_4]$ *considered as 100.*

Culture number.	Group A $[(NH_4)_2SO_4]$.			Group B $[NH_4\ NO_3]$.			Group C $[Ca\ (NO_3)_2]$.			Group D $[Na\ NO_3]$.		
	Relative, Set 1.	Relative, Set 2.	Relative average for 2 Sets.	Relative, Set 1.	Relative, Set 2.	Relative average for 2 Sets.	Relative, Set 1.	Relative, Set 2.	Relative average for 2 Sets.	Relative, Set 1.	Relative, Set 2.	Relative average for 2 Sets.
R1C1	100 (77)	100 (45)	100	60	82	71	47	49	48	47	49	48
C2	100 (149)	100 (85)	100	40	75	58	23	36	30	26	49	38
C3	100 (169)	100 (139)	100	39	63	51	22	35	29	22	34	28
C4	100 (197)	100 (190)	100	58	71	65	23	33	28	20	32	26
C5	100 (174)	100 (162)	100	53	88	71	28	54	41	28	55	42
R2C1	100 (94)	100 (53)	100	49	62	56	23	38	31	30	42	36
C2	100 (97)	100 (66)	100	49	94	72	35	65	50	42	68	55
C3	100 (145)	100 (122)	100	51	92	72	22	75	49	29	63	46
C4	100 (166)	100 (167)	100	55	84	70	25	53	39	32	68	50
R3C1	100 (53)	100 (67)	100	75	63	69	43	45	44	72	36	54
C2	100 (89)	100 (107)	100	63	59	61	36	53	45	47	42	45
C3	100 (131)	100 (146)	100	60	75	68	28	58	43	24	54	34
R4C1	100 (59)	100 (83)	100	69	34	52	53	33	43	58	29	44
C2	100 (111)	100 (106)	100	61	62	62	32	48	40	21	48	35
R5C1	100 (57)	100 (61)	100	86	66	76	60	34	47	65	41	53
Av.	100	100	100	—	—	65	—	—	40	—	—	42

TABLE VIII.—*Index values showing the relative yield of straw per unit of molecular nitrogen added to the cultures. For Set 1.*

Culture number.	[a] Units of nitrogen. U_n.	$(NH_4)_2SO_4$.		NH_4NO_3.		$Ca(NO_3)_2$.		$NaNO_3$.	
		Yield.	*Yield.* U_n.	Yield.	*Yield.* U_n.	Yield.	*Yield.* U_n.	Yield.	*Yield.* U_n.
R1C1	1	67	67	43	43	33	33	35	35
C2	2	137	69	55	28	42	21	39	20
C3	3	135	45	60	20	35	12	43	14
C4	4	177	45	111	28	46	12	44	11
C5	5	173	35	77	15	50	10	48	10
R2C1	1	82	82	53	53	35	35	38	38
C2	2	84	42	49	25	39	20	47	24
C3	3	144	48	66	22	36	12	39	13
C4	4	146	37	87	22	50	13	47	12
R3C1	1	53	53	42	42	28	28	39	39
C2	2	80	40	55	28	31	16	38	19
C3	3	110	37	72	24	37	12	36	12
R4C1	1	56	56	40	40	36	36	36	36
C2	2	104	52	66	33	38	19	37	19
R5C1	1	58	58	43	43	38	38	36	36
Maximum	5	177	82	111	43	50	38	48	38
Minimum	1	53	40	40	15	28	10	35	10
Mean	2	108	51	61	31	38	21	40	23

[a] The units of nitrogen here given are proportional to the number of gram-molecules of nitrogen. The actual number of gram-molecules of N_2 may be obtained by multiplying U_n by 0.0429.

TABLE IX.—*Index values showing the relative yield of straw per unit of molecular nitrogen added to the cultures. For Set 2.*

Culture number.	[a] Units of nitrogen. U_n.	$(NH_4)_2SO_4$.		NH_4NO_3.		$Ca(NO_3)_2$		$NaNO_3$.	
		Yield.	*Yield.* U_n.	Yield.	*Yield.* U_n.	Yield.	*Yield.* U_n.	Yield.	*Yield.* U_n.
R1C1	1	42	42	30	30	19	19	27	27
C2	2	74	37	63	32	35	18	41	21
C3	3	102	34	88	29	52	17	47	16
C4	4	130	33	126	32	51	13	63	16
C5	5	141	28	134	27	69	14	91	18
R2C1	1	47	47	35	35	26	26	28	28
C2	2	96	48	66	33	45	23	48	24
C3	3	122	41	110	37	88	29	84	28
C4	4	148	37	135	34	85	21	96	24
R3C1	1	59	59	41	41	28	28	29	29
C2	2	116	58	58	29	61	31	45	23
C3	3	143	48	100	33	75	25	70	23
R4C1	1	98	98	40	40	30	30	35	35
C2	2	122	61	76	38	46	23	56	28
R5C1	1	76	76	51	51	23	23	33	33
Maximum	5	148	98	135	51	88	30	96	35
Minimum	1	42	28	30	27	23	13	27	16
Mean	2	101	50	77	35	49	23	53	25

[a] The units of nitrogen here given are proportional to the number of gram-molecules of nitrogen. The actual number of gram-molecules of N_2 may be obtained by multiplying U_n by 0.0429.

TABLE X.—*Index values showing the relative yield of grain per unit of molecular nitrogen added to the cultures. For Set 1.*

Culture number.	[a]Units of nitrogen. U_n.	$(NH_4)_2SO_4$.		NH_4NO_3.		$Ca(NO_3)_2$.		$NaNO_3$.	
		Yield.	*Yield.* U_n.	Yield.	*Yield.* U_n.	Yield.	*Yield.* U_n.	Yield.	*Yield.* U_n.
		gm.		*gm.*		*gm.*		*gm.*	
R1C1	1	77	77	46	46	36	36	36	36
C2	2	149	75	59	30	34	17	39	20
C3	3	169	56	65	22	38	13	38	13
C4	4	197	49	115	29	45	11	40	10
C5	5	174	35	92	18	48	10	48	10
R2C1	1	94	94	46	46	22	22	28	28
C2	2	97	49	48	24	34	17	41	20
C3	3	145	48	74	24	32	11	42	14
C4	4	155	42	92	23	42	10	53	13
R3C1	1	53	53	40	40	23	23	38	38
C2	2	89	45	56	28	32	16	42	21
C3	3	131	44	78	26	37	12	31	10
R4C1	1	59	59	41	41	31	31	34	34
C2	2	111	56	68	34	35	18	33	17
R5C1	1	57	19	49	16	34	11	37	12
Maximum	5	197	94	115	46	48	36	53	38
Minimum	1	53	19	41	16	22	10	28	10
Mean	2	118	53	65	30	35	17	39	20

[a] The units of nitrogen here given are proportional to the number of gram-molecules of nitrogen. The actual number of gram-molecules of N_2 may be obtained by multiplying U_n by 0.0429.

TABLE XI.—*Index values showing the relative yield of grain per unit of molecular nitrogen added to the cultures. For Set 2.*

Culture number.	[a]Units of nitrogen. U_n.	$(NH_4)_2SO_4$.		NH_4NO_3.		$Ca(NO_3)_2$.		$NaNO_3$.	
		Yield.	*Yield.* U_n.	Yield.	*Yield.* U_n.	Yield.	*Yield.* U_n.	Yield.	*Yield.* U_n.
		gm.		*gm.*		*gm.*		*gm.*	
R1C1	1	45	45	37	37	22	22	22	22
C2	2	85	43	64	32	31	16	42	21
C3	3	139	46	87	29	49	16	47	16
C4	4	190	48	134	34	62	16	60	15
C5	5	162	32	143	29	87	17	89	18
R2C1	1	53	53	33	33	20	20	22	22
C2	2	66	33	62	31	43	22	45	23
C3	3	122	41	112	37	91	30	77	26
C4	4	167	42	141	35	88	22	113	28
R3C1	1	67	67	42	42	30	30	24	24
C2	2	107	54	63	32	57	29	45	23
C3	3	146	49	110	37	84	28	79	26
R4C1	1	83	83	28	28	27	27	24	24
C2	2	106	53	66	33	51	26	51	26
R5C1	1	61	61	40	40	21	21	25	25
Maximum	5	190	83	143	42	91	30	113	28
Minimum	1	45	32	28	28	20	16	22	15
Mean	2	107	50	77	34	51	21	51	23

[a] The units of nitrogen here given are proportional to the number of gram-molecules of nitrogen. The actual number of gram-molecules of N_2 may be obtained by multiplying U_n by 0.0429.

Considering both straw and grain yields, the best culture supplied with $(NH_4)_2 SO_4$ gave a yield about 9.6 times the yield of the control culture, which received no fertilizer; the best culture with NH_4NO_3 gave a yield about 6.5 times the yield of the control; the best culture with $Ca(NO_3)_2$ gave a yield about 3.0 times the yield of the control; and the best culture with $NaNO_3$ gave a yield about 3.2 times the yield of the control. These results indicate clearly that ammonium nitrogen was much more effective than nitrate nitrogen in increasing the yield of both straw and grain. Nitrate nitrogen is not to be regarded, however, as being without influence upon rice growing in water-saturated soil.

For every set of salt proportions, yields of grain and of straw per unit of molecular nitrogen added to the cultures were highest when the nitrogen was added as ammonium sulphate; they were lower when the nitrogen was supplied as ammonium nitrate; and they were still lower when the nitrogen was supplied as calcium nitrate or as sodium nitrate.

The proportions of primary calcium phosphate and potassium sulphate appeared to influence, though slightly, the relationships between the nitrogenous salts and the yields.

It must be emphasized that in experiments of this kind the results must be interpreted with respect to the particular experimental conditions used. The results of the present study might have been very different had another variety of rice, another soil, or other climatic conditions been employed.

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IN MEMORIAM

VALENTIN ERESE

GRADUATED FROM THE
COLLEGE OF AGRICULTURE,
CLASS OF 1919

DIED MAY 18, 1920
AT
TARLAC, TARLAC

COLLEGE AND ALUMNI NOTES

Prof. Charles H. Tuck, now U. S. Commissioner of Agriculture to Russia, visited the College on May 17. Professor Tuck was formerly head of the Extension Department at Cornell University, New York. For the past four years he has been in the Orient as a special agent of the United States Government looking after industrial developments. The first three years were spent in Manchuria and the past year in Siberia. He is on his way to Russia, and stopped in the Islands for a period of about ten days. He expressed himself as "agreeably surprised" at the work carried on at the College of Agriculture and asked numerous questions regarding the educational work in the Philippines.

A party from the Manila office of the Mitsui Bussan Kaisha, Ltd., visited the College on Sunday, May 30, and were shown over the grounds by Professor Ashton. They seemed impressed with the size and beauty of the campus. Noting the absence of wistaria, they promised to secure some for us at an early date. The party consisted of Mr. and Mrs. S. Mori, Mrs. Funatsu, and Messrs. Asai, Suzukim, and Asada.

On June 8, 1920, Mr. Edward H. Taylor, formerly of the Bureau of Science, came to the College to study the zoological specimens in the collection of the College of Agriculture. Mr. Taylor is a specialist in reptiles and batrachians. The College appreciates his kindness in classifying and making accurate determinations of those groups for the zoology department. In the collection he discovered a number of very rare specimens. It includes a true toad, *Bufo*, which Mr. Taylor says is the only specimen ever reported from Luzon; one species of house lizard, *Hemidactylus garnetii;* a species of skink, *Otosaurus cumingii;*and five species of snakes: namely *Psammodynastes pulverulentus*, slightly poisonous; *Dendrolaphis modestus*, Beulenger, harmless; *Hoiogherrum philippinum*, very rare and harmless; *Boiga angulata*, slightly poisonous, and *Dryophiops philippina*, slightly poisonous, harmless. The complete list includes one species of toad, nine of frogs, fourteen of lizards, and twenty-six species of snakes. This list does not fully represent the reptilian and batrachian fauna of this locality, for these specimens classified and determined by Mr. Taylor are only a year's collection made by the class in agricultural zoology under the direction of Mr. Deogracias Villadolid.

Evett D. Hester, associate professor of economics, went on leave April 5, sailing from Manila on April 12 on the U. S. A. T. *Great Northern* for the United States. Professor Hester expects to return to the university late in June.

Emma Sarepta Yule, associate professor of English, left in April for Japan, Korea, and China for the purpose of gathering data regarding the relation of oriental woman to agriculture. Professor Yule expects to return to the university about July 1.

Forman T. McLean, professor of plant physiology, went on leave April 5, sailing from Manila on the U. S. A. T. *Great Northern*, April 12. Professor McLean expects to be gone for about six months.

O. A. Reinking, professor of plant pathology, left for Siam and Straits Settlements in April. Under assignment by the U. S. Department of Agriculture, Professor Reinking will study the citrus diseases in these regions. He expects to return about the end of July.

During the month of April, Professor B. M. Gonzalez, of the Department of Animal Husbandry, went on a trip to Nueva Vizcaya and the Mountain Province at the invitation of the director of the Bureau of Non-Christian Tribes. The purpose of the trip was to select suitable sites for government cattle ranches in that region. He reports having found two very desirable sites, and several others that could be used. He went through Nueva Vizcaya first, then the sub-provinces of Ifugao, Bontoc, and Kalinga, and on to the northern coast through Cagayan. From Aparri he took a steamer to Currimao, Ilocos Norte, continuing by land through the sub-provinces of Amburayan, Lepanto, and Benguet, to Baguio.

Florentino F. Cruz, '16, who was in charge of the Crescent Star Cattle Company, a successful cattle ranch in Mindanao, located at Dagumbaan, Bukidnon, has resigned from the government service to accept an offer with the Hamilton interests. He will establish another cattle ranch for the company in Impalutao, Bukidnon. Mr. Cruz is to receive a substantial increase in salary and a percentage of the net profits, and will have the privilege of starting his own herd on an adjoining ranch.

WEATHER OBSERVATIONS, OCTOBER, 1919.

Observer—R. P. Estioko

At College

Date.	Rainfall.		Temperature.				Wind.		Cloudiness.
	Daily.	Weekly.	Maximum.	Minimum.	Mean.		Daily.	Weekly.	
					Daily.	Weekly.			
October	*mm.*	*mm.*	°*C.*	°*C.*	°*C.*	°*C.*	*miles.*	*miles.*	
1	.0		29.5	22.6	26.1		21.2		¾ cloudy
2	.0		31.5	21.6	26.6		17.5		¾ cloudy
3	.8		31.0	23.6	27.3		29.4		¾ cloudy
4	.5	1.3	31.0	23.6	27.3	26.5	21.9	151.2	¾ cloudy
5	.0		31.0	23.6	27.3		20.4		½ cloudy
6	.0		30.0	23.6	26.8		16.3		¾ cloudy
7	5.0		27.5	23.6	25.6		14.7		cloudy
8	20.0		25.5	22.6	24.1		11.6		cloudy
9	62.4		26.0	23.1	24.6		19.4		cloudy
10	24.1		28.0	23.6	25.8		52.5		¾ cloudy
11	3.7	115.2	29.0	23.6	26.3	25.8	38.7	173.6	cloudy
12	T.		30.0	23.6	26.8		20.3		cloudy
13	.0		29.5	22.6	26.1		23.3		¾ cloudy
14	3.7		27.5	23.1	25.3		20.1		cloudy
15	106.6		27.0	22.6	24.8		42.5		cloudy
16	8.5		29.0	23.1	26.1		107.2		cloudy
17	12.0		31.5	24.1	27.8		58.7		cloudy
18	3.8	134.6	28.5	23.6	26.1	26.1	26.1	298.2	¾ cloudy
19	1.5		29.5	23.1	26.3		28.5		½ cloudy
20	72.1		27.5	23.1	25.3		14.5		cloudy
21	.5		27.5	23.6	25.6		49.5		½ cloudy
22	.7		27.0	22.6	24.8		23.5		cloudy
23	.0		29.0	23.6	26.3		20.8		½ cloudy
24	T.		28.0	22.6	25.3		29.1		½ cloudy
25	89.7	164.5	26.0	23.1	24.6	25.5	28.8	194.7	¾ cloudy
26	10.9		27.5	22.6	25.1		13.7		cloudy
27	30.0		25.5	23.1	24.3		12.9		¾ cloudy
28	T.		28.0	23.1	25.6		24.7		¾ cloudy
29	2.5		27.5	23.6	25.6		27.9		¾ cloudy
30	4.8		27.5	23.6	25.6		14.2		¾ cloudy
31	11.2		28.0	23.1	25.6		43.7		½ cloudy
Monthly		475.0	28.4	23.2	25.8			893.6	

On Mount Makiling

Station on Mount Makiling.	Dates.	Rainfall.	Temperature.		
			Maximum.	Minimum.	Mean.
		mm.	°*C.*	°*C.*	°*C.*
Coffee Plantation	Oct. 6 to Oct. 12	152.0	31.0	20.5	25.8
	Oct. 13 to Oct. 19	125.2	30.5	20.0	25.3
	Oct. 20 to Oct. 26	61.2	28.5	20.0	24.3
	Oct. 27 to Nov. 2	95.5	27.0	20.5	23.8
450 m. Elevation, Mt. Makiling	Oct. 6 to Oct. 12	146.7			
	Oct. 13 to Oct. 19	136.6			
	Oct. 20 to Oct. 26	73.4			
	Oct. 27 to Nov. 2	82.2			
Summit of Mount Makiling	Oct. 6 to Oct. 12	127.4	19.9	17.9	18.9
	Oct. 13 to Oct. 19	94.6	20.3	17.8	19.1
	Oct. 20 to Oct. 26	67.4	19.1	17.8	18.5
	Oct. 27 to Nov. 2	102.4	19.7	18.5	19.1

WEATHER OBSERVATIONS, NOVEMBER, 1919.

Observer—R. P. Estioko

At College

Date.	Rainfall.		Temperature.				Wind.		Cloudiness.
	Daily.	Weekly.	Maximum.	Minimum.	Mean. Daily.	Mean. Weekly.	Daily.	Weekly.	
Nov.	*mm.*	*mm.*	*°C.*	*°C.*	*°C.*	*°C.*	*miles.*	*miles.*	
1	23.1	82.5	28.0	23.6	25.8	25.4	21.1	158.2	cloudy
2	.3		27.5	23.1	25.3		25.6		½ cloudy
3	T.		29.0	24.1	26.6		41.3		½ cloudy
4	6.5		29.0	23.6	26.3		29.8		½ cloudy
5	3.4		29.0	24.1	22.6		8.6		cloudy
6	4.4		28.0	23.1	25.6		76.7		½ cloudy
7	4.0		28.0	23.1	25.6		30.7		½ cloudy
8	3.5	22.1	28.0	22.6	25.3	25.9	23.6	236.3	¾ cloudy
9	.0		29.0	22.6	25.8		13.5		¾ cloudy
10	T.		29.0	22.6	25.8		20.6		¾ cloudy
11	12.0		29.0	22.6	25.8		42.9		½ cloudy
12	.0		29.0	23.6	26.3		18.9		½ cloudy
13	.0		28.0	23.1	25.6		37.0		cloudy
14	.0		27.5	21.6	24.6		34.5		¾ cloudy
15	.0	12.0	26.5	23.6	25.1	25.6	65.5	232.9	¾ cloudy
16	.0		27.5	22.6	25.1		40.2		¾ cloudy
17	.0		27.5	22.6	25.1		28.3		¾ cloudy
18	37.1		24.5	23.6	24.1		86.3		cloudy
19	11.0		28.5	22.6	25.6		45.7		½ cloudy
20	15.3		27.0	22.6	24.8		38.8		¾ cloudy
21	T.		28.0	22.6	25.3		26.1		¾ cloudy
22	15.8	79.2	26.0	23.1	24.6	24.9	58.4	323.8	cloudy
23	.0		26.5	23.1	24.8		53.1		¾ cloudy
24	.2		25.0	22.4	23.7		49.7		cloudy
25	4.0		25.0	20.6	22.8		51.0		cloudy
26	.0		26.5	20.6	23.6		43.4		½ cloudy
27	17.2		26.0	22.6	24.3		30.4		cloudy
28	4.1		28.5	23.6	26.1		56.5		cloudy
29	27.8	53.3	26.5	23.6	25.1	24.3	33.6	317.7	cloudy
30	10.2		27.0	23.6	25.3		24.7		cloudy
Monthly		199.9	27.5	22.9	25.2			1156.5	

On Mount Makiling

Station on Mount Makiling.	Dates.	Rainfall.	Temperature. Maximum.	Minimum.	Mean.
		mm.	*°C.*	*°C.*	*°C.*
Coffee Plantation	Nov. 3 to Nov. 9	34.5	28.0	20.2	24.1
	Nov. 10 to Nov. 16	31.5	28.5	19.5	24.0
	Nov. 17 to Nov. 23	77.4	28.0	20.0	24.0
	Nov. 24 to Nov. 30	86.5	27.5	19.5	23.5
450 m. Elevation, Mt. Makiling	Nov. 3 to Nov. 9	39.6			
	Nov. 10 to Nov. 16	25.3			
	Nov. 17 to Nov. 23	83.6			
	Nov. 24 to Nov. 30	89.6			
Summit of Mount Makiling	Nov. 3 to Nov. 9	41.4	19.5	17.9	18.7
	Nov. 10 to Nov. 16	35.8	18.8	17.2	18.0
	Nov. 17 to Nov. 23	72.5	18.9	17.3	18.1
	Nov. 24 to Nov. 30	91.2	18.6	17.2	17.9

WEATHER OBSERVATIONS, DECEMBER, 1919

Observer—R. P. Estioko

At College

Date.	Rainfall.		Temperature.				Wind.		Cloudiness.
	Daily.	Weekly.	Maximum.	Minimum.	Mean.		Daily.	Weekly.	
					Daily.	Weekly.			
Dec.	*mm.*	*mm.*	°*C.*	°*C.*	°*C.*	°*C.*	*miles.*	*miles.*	
1	12.7		27.0	22.6	24.8		47.1		cloudy
2	6.4		27.8	23.1	25.5		65.7		¾ cloudy
3	5.5		27.0	23.6	25.3		35.0		cloudy
4	11.9		25.5	22.6	24.1		25.2		cloudy
5	11.5		27.0	23.6	25.3		22.8		cloudy
6	13.4	61.6	28.0	23.6	25.8	25.2	39.4	259.9	cloudy
7	T.		29.0	23.6	26.3		125.3		¾ cloudy
8	.0		29.0	22.6	25.8		16.3		½ cloudy
9	.0		28.5	23.1	25.8		28.9		½ cloudy
10	12.5		25.5	22.6	24.1		38.9		cloudy
11	2.7		28.0	21.6	24.8		32.2		¼ cloudy
12	.0		28.0	22.6	25.3		45.2		¾ cloudy
13	.0	15.2	27.2	21.6	24.4	25.2	33.1	319.9	cloudy
14	.0		26.0	23.6	24.8		46.3		cloudy
15	T.		27.0	22.6	24.8		32.5		cloudy
16	.0		26.0	23.6	24.8		43.0		cloudy
17	T.		26.0	23.1	24.6		47.8		cloudy
18	1.1		26.0	22.6	24.3		36.9		cloudy
19	1.0		26.0	22.6	24.3		36.1		cloudy
20	.0	2.1	26.5	22.6	24.6	24.6	28.9	266.5	cloudy
21	2.6		26.0	22.6	24.3		58.1		cloudy
22	1.2		26.0	21.6	23.8		32.1		cloudy
23	.8		26.0	22.4	24.2		28.0		cloudy
24	.0		27.8	23.1	25.5		39.7		½ cloudy
25	.0		27.0	22.5	24.8		30.1		clear
26	10.6		26.2	23.6	24.9		12.0		½ cloudy
27	.0	15.2	27.0	23.0	25.0	24.6	29.1	229.1	cloudy
28	.0		26.5	23.1	24.8		28.9		clear
29	30.2		24.0	22.1	23.1		33.6		cloudy
30	.0		22.2	21.1	21.7		61.4		¾ cloudy
31	.0		23.0	20.7	21.9		33.5		clear
Monthly		124.1	26.5	22.7	24.6			1213.1	

On Mount Makiling

Station on Mount Makiling.	Dates.	Rainfall.	Temperature.		
			Maximum.	Minimum.	Mean.
		mm.	°*C.*	°*C.*	°*C.*
Coffee Plantation	Dec. 1 to Dec. 6	88.2	25.5	19.0	22.3
	Dec. 7 to Dec. 13	43.5	28.0	19.0	23.5
	Dec. 14 to Dec. 20	10.9	24.0	19.9	22.0
	Dec. 21 to Dec. 26	11.9	27.0	22.0	24.5
	Dec. 27 to Jan. 2	23.5	24.2	17.0	20.6
450 m. Elevation, Mt. Makiling	Dec. 1 to Dec. 6	63.4			
	Dec. 7 to Dec. 13	43.2			
	Dec. 14 to Dec. 20	6.5			
	Dec. 21 to Dec. 26	12.5			
	Dec. 27 to Jan, 2	23.1			
Summit of Mount Makiling	Dec. 1 to Dec. 6	51.2	19.3	18.2	18.8
	Dec. 7 to Dec. 13	34.6	19.9	18.0	19.0
	Dec. 14 to Dec. 20	15.5	17.7	16.5	17.1
	Dec. 21 to Dec. 26	20.9	19.0	17.2	18.1
	Dec. 27 to Jan. 2	33.5	17.3	15.7	16.5

WEATHER OBSERVATIONS, JANUARY, 1920

Observer—R. P. Estioko

At College

Date.	Rainfall.		Temperature.				Wind.		Cloudiness.
	Daily.	Weekly.	Maximum.	Minimum.	Mean.		Daily.	Weekly.	
					Daily.	Weekly.			
Jan.	*mm.*	*mm.*	*°C.*	*°C.*	*°C.*	*°C.*	*miles.*	*miles.*	
1	.0		24.0	20.6	22.3		34.4		clear
2	.6		25.5	20.6	23.1		24.1		cloudy
3	2.1	32.9	26.0	23.1	24.6	23.1	43.1	259.0	cloudy
4	33.0		26.0	22.6	24.3		33.3		cloudy
5	14.0		24.0	21.1	22.6		68.6		cloudy
6	.0		25.0	22.6	23.8		18.7		cloudy
7	6.5		25.0	21.6	23.3		20.7		cloudy
8	.6		27.0	21.6	24.3		18.8		cloudy
9	.0		24.4	21.6	23.0		22.8		cloudy
10	.0	54.1	27.0	22.6	24.8	23.7	37.5	220.4	cloudy
11	.0		28.0	22.1	25.1		19.4		¾ cloudy
12	.0		28.0	22.6	25.3		111.2		cloudy
13	3.6		25.0	22.6	23.8		68.9		cloudy
14	.0		24.0	21.6	22.8		113.0		cloudy
15	.0		24.0	21.4	22.7		45.3		cloudy
16	.3		25.0	21.8	23.4		69.4		cloudy
17	1.9	5.8	25.8	22.1	23.5	23.8	34.2	461.4	cloudy
18	18.6		25.0	21.6	23.3		54.0		cloudy
19	1.7		25.0	21.6	23.3		66.3		¾ cloudy
20	.0		26.0	21.1	23.6		56.8		½ cloudy
21	.0		26.5	20.6	23.6		63.6		½ cloudy
22	.0		26.5	21.6	24.1		56.6		¾ cloudy
23	.0		26.0	20.6	23.3		60.1		½ cloudy
24	.0	20.3	26.0	18.6	22.3	23.4	39.3	396.7	clear
25	.0		26.8	20.6	23.7		50.6		¾ cloudy
26	.0		25.5	20.6	23.1		44.4		cloudy
27	.0		27.0	21.6	24.3		53.6		½ cloudy
28	.0		27.0	20.6	23.8		27.4		cloudy
29			28.5	21.1	24.8		22.4		¾ cloudy
30	.0		28.2	21.6	24.9		38.2		¾ cloudy
31	.0	.0	28.5	22.6	25.6	24.3	34.4	271.0	cloudy
Monthly		82.9	26.0	21.5	23.8			1451.1	

On Mount Makiling

Station on Mount Makiling.	Dates.	Rainfall.	Temperature.		
			Maximum.	Minimum.	Mean.
		mm.	*°C.*	*°C.*	*°C.*
Coffee Plantation	Jan. 3 to Jan. 9	29.5	26.0	17.0	21.5
	Jan. 10 to Jan. 16	46.5	27.2	18.0	22.9
	Jan. 17 to Jan. 23	13.1	25.0	17.0	21.0
	Jan. 24 to Jan. 30	3.5	28.0	18.0	23.0
450 m. Elevation, Mt. Makiling	Jan. 3 to Jan. 9	29.1			
	Jan. 10 to Jan. 16	39.5			
	Jan. 17 to Jan. 23	16.8			
	Jan. 24 to Jan. 30	3.7			
Summit of Mt. Makiling	Jan. 3 to Jan. 9	41.9	19.1	17.7	18.4
	Jan. 10 to Jan. 16	56.8	19.3	16.3	17.8
	Jan. 17 to Jan. 23	8.5			
	Jan. 24 to Jan. 30	6.3	19.3	16.7	18.0

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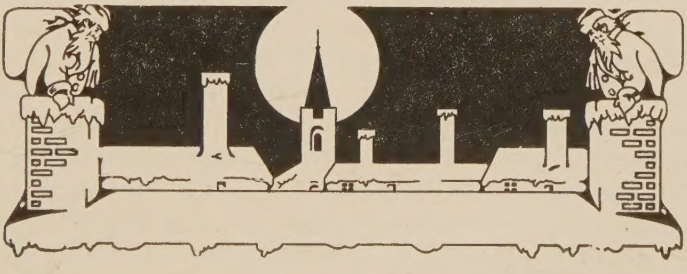

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